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# KNOWLEDGE-BASED INTEGRATED SUSTAINABLE AGRICULTURE AND NUTRITION (KISAN) PROJECT

POST HARVEST SYSTEMS IN KISAN PROJECT AREA AND  
RECOMMENDATIONS

CONTRACT NUMBER AID-367-C-13-00004

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# KISAN

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## ACRONYMS

APMC	Agricultural Produce Marketing Committee
CIMMYT	International Maize and Wheat Improvement Center
CRSP	Collaborative Research Support Program
DADO	District Agriculture Development Office
DFTQC	Department of Food Technology and Quality Control
EC	Emulsifiable Concentrate
FAO	United Nations Food and Agricultural Organization
FFS	Farmer Field School
FTF	Feed the Future
GON	Government of Nepal
HDPE	High Density Poly Ethylene
Ha	Hectare
HH	Household
ICARDA	International Center for Agricultural Research in the Dry Area
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IRRI	International Rice Research Institute
KISAN	Knowledge-based Integrated Sustainable Agriculture and Nutrition
MPC	Market Planning Committees
NARC	Nepal Agricultural Research Council
NRs	Nepali Rupees
OPV	Open pollinated varieties
PICS	Purdue Improved Crop Storage
ppm	Parts per million
RH	Relative humidity
RPC	Returnable plastic crate system
USAID	U.S. Agency for International Development
WBE	Woven polypropylene bag
WFP	World Food Program

## EXECUTIVE SUMMARY

At the request of the Knowledge-based Integrated Sustainable Agriculture and Nutrition (KISAN) Project (Contract Number AID 367-C-13-00004), post-harvest expert Dr. Kerstin Hell visited Nepal November 27 – December 15, 2013. Dr. Hell had the opportunity to see examples of current post-harvest practices in the rice, maize, lentil, and vegetable value chains. During the visit, Dr. Hell talked with many individuals from both the public and private sectors and developed a strategy to improve post-harvest practices for these sectors. Dr. Hell appreciates the support that she received from the KISAN team during her time in Nepal.

This report describes the post-harvest situation of the rice, maize, lentil, and vegetable value chains in Nepal and major technological and possible management changes that the KISAN Project can implement to reduce post-harvest losses in these value chains. Nepali farmers estimate their post-harvest losses in the rice, maize, and lentil to be about 10%, 15%-20%, and 10%, respectively. Based on our limited visits we suggest that post-harvest losses in the KISAN Zone of Influence (ZOI) could be much higher than the above estimates of the farmers. We have come to the conclusion that post-harvest losses of grains are a serious issue requiring much more attention than is currently being paid by national and international research organizations and donors. Post-harvest losses in vegetables varied widely depending on the type of vegetable and the point along the value chain. Farmers report losses to be 2%-5% on average in their field. Reported losses were recorded to be an average of 3%-5% at the collection center, 3%-5% at the wholesaler (depending on the crop), and 5%-7% at the retailer. None of these estimates take into account water losses during transport which would bring potential losses to well over 30%.

It is clear from this limited study that post-harvest issues are important in terms of health, productivity, and food security and is largely underappreciated by Government researchers, development partners, and to some extent farm households (HHs). It is suggested that KISAN give priority to disseminating post-harvest technologies first in the vegetable value chain, as vegetables are the most important in terms of income and suffer the highest losses for the stakeholder beneficiaries. However, the technologies required for this value chain require knowledge and the technologies required, such as cooling technologies, need more resources. The second priority value chain for investments is maize given its role in food security in the hills due to the unknown risks posed by mycotoxins, followed by rice and lentils.

Overall, it is suggested that KISAN consider the following:

### *High-Value Vegetables*

1. Inform vegetable producers on the timing and transport of harvest, as well as how to harvest and the key signs of maturity for each crop.
2. Use reusable plastic crates for packaging and transporting most vegetables. Work with stakeholders to determine the most convenient and acceptable system for organizing the crate system.

3. Work with wholesalers, farmers, and others on grading of vegetables.

#### *Rice*

4. When evaluating potential rice varieties, work with NARC and CSISA to include resistance to post-harvest pests as part of the evaluation criteria.
5. Promote combine harvesters, use mechanical threshers and tarpaulins to reduce losses during paddy threshing.
6. Use improved storage, such as hermetic storage bags and metal silos, to reduce post-harvest losses.

#### *Maize*

7. Evaluate the post-harvest quality of existing and new varieties.
8. Improve the existing storage structures and introduce improved storage, such as hermetic bags and metal silos.
9. Educate producers on the importance of keeping moisture out of grains and cobs. Promote the use of drying racks only until onset of rainy season, sun drying cobs and grain drying, and storage in hermetic bags. Additionally, the Grain Pro/IRRI solar bubble grain dryer might be tested in Nepal.

#### *Lentils*

10. Improve sorting and storage of lentils in hermetic bags. As in the case of cereals, hold the product until the prices increase which would increase potential benefits for producers.

#### *Across value chains*

11. For all value chains, there could be the potential to increase the use of collective marketing<sup>1</sup> to reduce transaction costs and increase potential benefits by marketing during periods of the year where higher prices are achieved. For vegetables, this means planting to produce during the off season, and for grains, that may mean holding the product until the price increases. This could also be linked to a credit input system and/or a warehouse receipt system<sup>2</sup> for value chain financing.

During the visit Dr. Hell was not able to assess what other institutions are working on the reduction of post-harvest losses in Nepal, so that complementarities and economies of scale could be exploited. On the research side, very few institutions are working on developing sustainable solutions within Nepal. However, within the sub-region and globally there are many partners like FAO, IRRI, CIMMYT, ICRISAT, University Davis, and the Postharvest Education Foundation that could be valuable technology providers.

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<sup>1</sup> [http://www.fao.org/sd/erp/toolkit/BOOKS/manual4\\_collectivemarketing.pdf](http://www.fao.org/sd/erp/toolkit/BOOKS/manual4_collectivemarketing.pdf)

<sup>2</sup> <http://nepal.mercycorps.org/pdf/ValueChainFinanceandNepal-PerspectivesandInsights.pdf>

The present assessment revealed a significant lack of reliable data on 1) the extent of post-harvest losses for the targeted crops in Nepal, particularly the lack of data on mycotoxin contamination in the crops; 2) existing post-harvest infrastructure and technologies in the country; and 3) few documents on existing efforts by private and public sector institutions to reduce post-harvest losses in the four value chains and major lessons learned. The consultant therefore concludes that research and development institutions must work to address data collection so that a more realistic assessment of the actual amount of losses and the associated health hazards can be made.

## I. INTRODUCTION

Within the scope of its Feed the Future (FTF) Strategy, USAID/Nepal has a project to increase incomes of smallholder farmers through sustainable intensification of high-value vegetables along with cereals and pulses. The overall goal of the Knowledge-based Integrated Sustainable Agriculture and Nutrition (KISAN) Project is to sustainably reduce poverty and hunger in Nepal by achieving inclusive growth in the agriculture sector, increasing income of farm families, and improving nutritional status, especially of women and children. The project follows market demand and trains farmers on improved production techniques through change agents. The project organizes collection centers to aggregate and market farmers' produce.

USAID/Nepal is implementing the project over a five-year period through an integrated, whole-of-government approach with strategic agriculture and nutrition investments, supporting contributions in cross-cutting areas. KISAN focuses on 20 Terai and lower hill districts in the Far-Western, Mid-Western, and Western regions of Nepal. KISAN focuses on three staple crops, namely maize, rice, and pulses and vegetables. KISAN also works on high-value vegetable crops such as cabbage, cauliflower, and tomatoes and minor crops (cucumber, pumpkin, onion, eggplant, okra, bottle gourd, bitter gourd, chili, and long beans).

One challenge that Nepal and Nepali farmers face is post-harvest losses in cereals and vegetables. Rough data estimates are that 10%-20% of cereals and possibly 25%-40% of vegetables are lost due a range of post-harvest issues<sup>3</sup>. In addition, the incidence of aflatoxin in cereals is thought to be a serious and unaddressed issue in Nepal. The prevalence of this toxin in multiple crops such as maize, peanut and, to a lesser degree, rice is a health risk for people and livestock and has recently been described as contributing to stunting<sup>4</sup>. Moreover, there have been several reports on *Fusarium* toxins in crops in Nepal<sup>5</sup>, which has been linked to esophageal cancer<sup>6</sup>. Most rural households store cereals in their homes that are not sufficiently dried, using storage methods that could promote fungal growth. They rarely use sealed bags or pest and moisture-resistant containers.

The purpose of this consultancy was to identify post-harvest practices and causes of losses in cereals (maize and rice), lentils, and high-value vegetables, identify potential solutions and technologies, and make pertinent recommendations in order to develop an action plan appropriate to KISAN to significantly reduce post-harvest losses.

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<sup>3</sup> Kader et al. <http://ucce.ucdavis.edu/files/datastore/234-1479.pdf>

<sup>4</sup> Gong, Y. Y., Cardwell, K., Hounsa, A., Egal, S., Turner, P. C., Hall, A. J., & Wild, C. P. (2002). Dietary aflatoxin exposure and impaired growth in young children from Benin and Togo: cross sectional study. *Bmj*, 325(7354), 20-21. <http://www.bmj.com/content/325/7354/20> AND [http://www.aflatoxinpartnership.org/~media/Files/Projects/Aflatoxin%20microsite/MycotoxinsandStunting\\_MeetingSummary\\_Final.pdf](http://www.aflatoxinpartnership.org/~media/Files/Projects/Aflatoxin%20microsite/MycotoxinsandStunting_MeetingSummary_Final.pdf)

<sup>5</sup> A. E. Desjardins, H. K. Manandhar, R. D. Plattner, G. G. Manandhar, S. M. Poling, and C. M. Maragos 2000. *Fusarium* Species from Nepalese Rice and Production of Mycotoxins and Gibberellic Acid by Selected Species. *Appl. Environ. Microbiol.* 66:1020-1025. <http://aem.asm.org/content/66/3/1020.full.pdf+html> AND Desjardins, A.E., Proctor, R.H., 2010. Genetic diversity and trichothecene chemotypes of the *Fusarium graminearum* clade isolated from maize in Nepal and identification of a putative new lineage. *Fungal Biol.* 115, 38-48. <http://naldc.nal.usda.gov/download/49485/PDF>

<sup>6</sup> Shephard, G. S. (2011). *Fusarium* mycotoxins and human health. *Plant Breeding and Seed Science*, 64(1), 113-121. <http://versita.metapress.com/content/x2v06q3h03867228/fulltext.pdf>

## A. BACKGROUND

The average land holding size of Nepali farmers has declined over the last decades. Today, farmers till on usually 0.7 hectares, with a mean of 1.26 ha in the Terai, 0.77 ha in the hills, and 0.68 hectares in the mountains<sup>7</sup>. On such small plots of land, farmers need to meet their annual food needs within two seasons. The cropping intensity varies from one to three crops per year, with a mean of 1.88. Furthermore, yields are low with 2.7t/ha, 1.8t/ha, and 0.85t/ha for rice, maize, and lentils, respectively.

In 1994, estimated rice losses in Nepal were 12.2%. No data could be found on loss levels in maize and lentils. Studies in 2001/02 have detailed post-harvest losses in vegetables in Nepal ranging from 10% to nearly 50%, with highest loss levels found at the retail level at 41%, 34%, 4.5%, and 7% respectively for cauliflower, cabbage, radish, and tomato. The losses were mainly due to spoilage, bruising, and trimmings in cauliflower and cabbage, breaking in radish and rupturing, and spoilage in tomatoes. Inappropriate packaging, transportation, and grading systems also contributed to post-harvest losses<sup>9</sup>.

Postharvest Losses of Vegetables in Nepal based on sampling (Udas et al, 2005)			
Vegetable	Farm (% loss)	Retail (% loss)	Total (% loss)
Cauliflower	6	41	47
Cabbage	9	34	43
Radish	6	4.5	10.5
Tomato	3	7	10

Figure 1. Post-harvest losses of vegetables in Nepal

According to the KISAN's PERSUAP<sup>10</sup> report, about 20% of the farmers were found treating harvested grains directly with pesticide to protect them from storage pests. The report states that farmers commonly apply aluminum phosphide (Celphos/Phostox tablets), which in countries with more advanced pesticide control systems can only be handled by licensed applicators. Farmers also used malathion (dust) and dichlorvos (Nuvan EC). Similarly, earlier studies have stated that grains used for human consumption are treated with pesticides. Six percent of the farmers applied the following insecticides on cereal grains: aluminum phosphide (Celphos tablets), malathion (dust), and dichlorvos (Nuvan EC)<sup>11</sup>.

Reducing post-harvest losses by training people on improved post-harvest technologies (PHT) is one important way KISAN can increase productivity. By applying best practices, farmers can 1) increase their incomes through the sales of high quality crops; 2) increase food security in the participating households by prolonging the storage period of their crops; and 3) increase reliance on own crops and improve access to nutritionally important vegetable crops. As farmers move from subsistence production to semi-commercial production, they need to be informed about post-harvest technologies for commercial crops that encompass all the many steps of food handling. These steps include initial harvesting and preparation for handling (selection, grading, and packaging), storage, transportation, agro-processing, and

<sup>7</sup> [http://www.ifad.org/evaluation/events/2013/nepal/nepal\\_cpe.pdf](http://www.ifad.org/evaluation/events/2013/nepal/nepal_cpe.pdf) p. 11

<sup>8</sup> <http://cpwfbfp.pbworks.com/f/Irrigation+and+Tenancy-Nepal.pdf>

<sup>9</sup> Udas, S., Rai, B. K., Gurung, M., Thapa, R., & Khatriwada, P. P. (2005). Assessment of postharvest handling systems of vegetables in the eastern hills of Nepal. *Acta horticulturae*.

<sup>10</sup> Litsinger, J. 2013. Pesticide evaluation report & safer use action plan (PERSUAP), November 25, 2013

<sup>11</sup> <https://www.tu-braunschweig.de/Medien-DB/geoekologie/nepal-shrestha-neupane.pdf>

marketing. Both male and female farmers and traders who market their own crops will benefit from reducing produce losses.

## **B. OBJECTIVE**

The KISAN Project employed the services of post-harvest and value chain specialist Dr. Kerstin Hell to assess the post-harvest system in Nepal. Based on the observed losses, Dr. Hell identified causes and key problems, made technical recommendations, and suggested best practices to the KISAN project staff.

## **C. SCOPE OF STUDY AND APPROACH**

Within the scope of the three week mission from the 27<sup>th</sup> of November to December 15<sup>th</sup>, Dr. Hell visited several KISAN intervention sites; see Annex I for further details on sites visited.

### **C.1 Information collection**

Information was collected during site visits and discussions with all actors along of the specific value chains. This includes meetings with key institutions that work to the improve the productivity of targeted value chains such as NARC (Head Office; Rampur, Maize Research Station; Khajura, Rice Research Station), Directorate of Postharvest Management, The University of Agriculture and Forestry, the District Agriculture Development Office (DADO) office in Surket and Banke, Plant Quarantine Officer at the Nepal/India border, and Regional Agriculture Directorate office (Surkhet). Furthermore, DFTQC and the CIMMYT/Hill Maize Program were visited to learn about their research concerning post-harvest quality and quality control. This was complemented by a literature review focusing on the prevalence of mycotoxins in commodities from Nepal.

#### *C.1.1 Government institutions working on reduction of post-harvest losses*

In addition to the above mentioned sources, special attention was given to the GON agencies that focus on post-harvest management. The Post-Harvest Management Directorate has done some research on methods and technologies to reduce post-harvest losses, published some documents regarding post-harvest losses, and trained staff. The GON staff based at this directorate in Kathmandu could be a resource for KISAN and used to train farmers. Specifically, there is a farmer field school (FFS) developed for maize in collaboration with the Rampur Maize Research Station and some research on small-scale cooling technologies for vegetables that needs to be further tested regarding its relevance in post-harvest vegetable systems. There is no regional staff with specific capacity in post-harvest management at the DADOs level.

#### *C.1.2 Limitations*

The collected information is based mostly on qualitative observations. The conclusions drawn from this assignment need to be supported by efforts to collect quantitative data on food losses from the field to consumption in the targeted commodities to confirm these findings. There is also need to address and quantify the potential levels of mycotoxins in Nepalese foods, targeting aflatoxin and fumonisin initially.

Within the mycotoxin study, there is also need to collect sufficient information on farming practices to be able to link higher toxin levels with adverse farming practices. This information will help determine cost-effective recommendations taking into consideration environmental factors to reduce the toxin risk, starting with improved management practices in the field. It would also be useful to link the exposure assessment with nutritional data and potentially health status, so that the wider impact of mycotoxins in Nepal could be assessed. However, these studies are very costly. Presently, the University of Michigan is studying the link between mycotoxin exposure and childhood stunting in Tanzania and Nepal<sup>12</sup>.

## II. FINDINGS FROM THE FIELD

All stakeholders were visited from production to consumption for the different commodity chains, with a key emphasis on observing postharvest systems. The team visited farmers, collectors, wholesalers, processors, millers, and retailers. The key observations are specified below.

### A. RICE

#### A.1 Description of observed post-harvest system

**Varieties:** According to a NARC report, Nepal has released 55 rice varieties in the last 40 years. The report states that the coverage by high yielding varieties (HYV) is 85% of the total rice cultivated land. Popularly cultivated improved varieties in the KISAN districts are Radha-4, Radha-12, Masuli, Sabitri, CH-45, and Bindeswori in Terai; Khumal-4, Sagu-52, Khumal-11, Taichung-176, and Chainung-242 in Mid-hills; and Chandannath-3 in High-hills<sup>13</sup>.

**Harvest:** The team observed that most farmers harvest rather late. Rice should be harvested when around 75% to 80% of the grains are golden yellow. According to the FAO, in general, the correct time to harvest is one week before the maturity date with a moisture content between 20% and 25%<sup>14</sup>. These authors stated that if rice is harvested at maturity, losses of 3.35% will have occurred; harvesting at two weeks after ripeness results in losses of 8.64%; and three weeks after maturity results in 40.70 % loss.

#### 1. Hybrid Rice

The hybrid rice varieties are reported by farmers to be more susceptible to post-harvest pests than local varieties. There is need to test the susceptibility of rice varieties to post-harvest pests in controlled conditions and feed the results into the breeding effort.

#### 2. Salt-Jar Method

The **salt-jar method** is a simple field method for determining whether grains are dry enough for storage in bags. A teaspoon full of dry non-iodized salt is placed in a thoroughly dry jar (or bottle) with a tight cover. The salt should not stick to the sides of the jar when it is rolled. Then grains are added and the cover sealed tightly. The jar is then shaken and rolled gently for 2–3 minutes. If the salt does not lump or adhere to the sides of the jar, the moisture is usually below 15%.

<sup>12</sup> [http://www.fshn.msu.edu/directory/felicia\\_wu](http://www.fshn.msu.edu/directory/felicia_wu)

<sup>13</sup> [http://www.narc.org.np/rice\\_knowledge\\_bank/](http://www.narc.org.np/rice_knowledge_bank/)

<sup>14</sup> An overview of rice post-harvest technology: use of small metallic silos for minimizing losses - D.J. Mejia <http://www.fao.org/docrep/006/y4751e/y4751e0o.htm> accessed on 12/1/14

Harvesting is with a few exceptions conducted manually with a simple sickle. Harvested panicles are bundled and heaped either in the field or transported to the threshing ground, which is sometimes near the house. It is possible to mechanize harvesting with either reaper binder, combine harvester, or stripper harvester which reduces losses from 4%-10% to 1%-2%<sup>15</sup>. Farmers in Nepal tend to leave harvested rice in piles on the threshing ground for further drying.

**Transport to the threshing ground:** Transport to the threshing ground is either by foot or with bullock-cart or tractor. Losses between the field and threshing ground can be high depending on the maturity of the rice. The more mature and dryer rice the higher the losses between the field and threshing ground as grains that are too mature will not hold and will fall during transport.

**Threshing:** Rice is left in piles on the threshing ground until farmers are ready to thresh. We observed heavy tunneling of mice under these piles. The objective of threshing is to detach paddy kernels from the panicle. It was observed that many farmers use trampling by humans, animals, trucks, or tractor to do this. However, the grain is



Figure 2: Rice in threshing ground

damaged in the process. Mechanical threshers are

also widely used in Nepal particularly in the terai – depending on the type of thresher used, losses and mechanical damage to the grain vary. One study from Iran compared losses from direct harvesting through rice combine harvesters with indirect harvesting, namely manual harvesting and/or reaper plus threshing. Total harvest loss was 2.94% when using the direct method<sup>16</sup> with combine and 4.88% with indirect harvesting.

Losses differ depending on the rice variety but may occur during threshing for various reasons:

- In manual threshing by beating or by animals, some grains remain in the panicles and a repeat threshing is required.
- Grain is scattered when the bundles are lifted just before threshing.
- Grain can stick in the mud floor.
- Birds and domestic fowls feed on the grain.

One farmer who was threshing immediately filled the rice grains into polypropylene bags. The team took a sample and observed that moisture levels were near 17%, levels well beyond safe storage which should be below 14% and 12% for long-term storage<sup>17</sup>. There is need to provide better tools for farmers to correctly determine safe levels of storage of grains, i.e. correctly determine moisture content of grains.

<sup>15</sup> <http://www.africarice.org/workshop/grisp-mech/PPT/Martin%20Gummert-IRRI.pdf>

<sup>16</sup> [http://www.irjabs.com/files\\_site/paperlist/r\\_767\\_130422105800.pdf](http://www.irjabs.com/files_site/paperlist/r_767_130422105800.pdf)

<sup>17</sup> <http://www.knowledgebank.irri.org/step-by-step-production/postharvest/drying/equilibrium-moisture-content>

Low-cost models of moisture meters should be available in India at around US\$100 to \$150. Furthermore, it would be possible for farmers to determine moisture content with the salt-jar method<sup>18</sup>.

**Winnowing:** Winnowing is used to clean grains from debris right after threshing. This is generally done by hand by smaller farmers and in the hills. This uses two actions: letting grains fall from over the head and letting the wind carry away lighter weighted debris, and using a round wicker frame to fan the grains and separate the grains from the chaff. Also, locally-produced manual and powered fan-type winnowers are widely used.



Figure 3: Losses in rice value chain

**Drying:** Rice is usually harvested at high moisture content of more than 20%. Farmers in Nepal store grains in piles on the threshing ground to dry their paddy which can lead to significant quality deteriorations. In the piles we observed mold infestation, humid patches, and insects.

Table I. Different drying methods: Technologies & characterization<sup>19</sup>

Method	Crop flow	Drying technology	Advantages	Disadvantages
Field drying		Piles, racks	Loosens the grain in the panicle for manual threshing	Rapid quality deterioration
Sun drying	Batch	Drying on pavements or mats	Cheap Labor intensive	Typically poor milling quality
Heated air drying	Batch	Fixed bed dryer Example: Flatbed dryer	Inexpensive, small scale operation possible Local construction from various materials Operation with unskilled labor	Moisture gradient Labor intensive
		Re-circulating batch dryer	Mixing of grain Large capacity range	Skilled laborers required

<sup>18</sup> <http://www.fao.org/docrep/015/i2433e/i2433e10.pdf>

<sup>19</sup> <http://www.knowledgebank.irri.org/rkb/paddy-drying-methods.html>

**Table I. Different drying methods: Technologies & characterization<sup>19</sup>**

Method	Crop flow	Drying technology	Advantages	Disadvantages
			Good quality	Medium capital investment After-sales service requirement Wear of moving components
	Continuous	Continuous flow dryer	Large capacity Economics of scale	High capital investment Not feasible for small batches of different varieties; complicated
<b>In-Store drying</b>	Batch	Storage bin with aeration components and pre-heater for adverse weather and nighttime	Excellent grain quality Large capacity range	Pre-drying of high moisture grain Risk of spoilage during power failure

Heat build-up in those piles can lead to discoloration/yellowing and odor build-up. We observed several farmers sun-drying their threshed rice paddy prior to storage – farmers stated they usually dried the rice for a maximum of three to seven days. Farmers will often re-dry stored rice. Rice is placed on plastic sheets or mats for sun-drying, or on the bare ground that has been specially prepared. Quality of sun-dried paddy depends on the thickness of the layer of paddy grains, ideally two to four cm, and on the mixing frequency every 30 minutes. There is need to cover the grains when temperatures rise above 50-60°C and during rain. Additionally, animals should be kept off the grains to prevent contamination.

**Storage:** Storability of commodities is affected by four factors: temperature, moisture content, container atmosphere (O<sub>2</sub> level), and type of storage container. In the Terai and Mid-hills households (HHs), rice was primarily stored in woven polypropylene bags or re-used feed and fertilizer bags (over 60%). Rice was also stored in metal bins, traditional stores made from bamboo (*bakari*) slightly lifted off the ground, mud stores (*daheri- mud coated bamboo*), smaller mud jars (*ghyampo*), and a few large wooden storage boxes. The cost of polypropylene bags in local markets is NRS 25-50 (simple rice storage bags).



Figure 4: Supergrain bag

Farmers stated that the more traditional structures (wooden storage boxes, mud store) are probably disappearing due to the increasing cost of wood and lack of skills for building mud stores as older members of the community are the holders of this traditional knowledge.

Farmers observed that traditional stores last a long time: bamboo lasts more than 20 years; 50 years and more for wood if there is no termite infestation; mud stores are maintained and resurfaced each year. All stores are usually well cleaned prior to storing the new harvest.

Extension services and research institutions have been testing storage of rice and maize in supergrainbags<sup>20</sup>. They are available at NRS 275 through licensed dealers, but none of the Agrovets visited carried this bag. Purdue University has also found a local manufacturer and distributor NAF Seeds Pvt. Ltd in Nepal for their Purdue Improved Crop Storage (PICS) bags. These bags cost slightly less, an estimated NRS 215.<sup>21</sup> In both cases, almost 50% of the cost is for duties on plastic.

Metal grain bins can be purchased for approximately NRs 2,000 in local metal working shops for bins of about 200 l; discussions were held with dealers to evaluate their use. One trader stated that she sells 30 grain bins per month during the harvest period. She has employed metalworkers from northern India to fabricate the grain bins. Some projects are distributing these metal grain bins, but in very low numbers (13 in Surket region). There is still some doubt if these bins are the best option in areas that have high day to night temperature differences, as there could be risk of condensation on the inside the metal bins. So there is need for testing of these stores in varying climatic conditions, including hot and humid conditions. Also, high initial cost could be a constraint to adoption of metal grain bins.

**Milling:** Hand pounding of paddy in a mortar with a pestle is the traditional milling process in remote villages. Several types of mills were observed:

*Single pass, single stage mill* – The "iron hullers" or "single pass mills" result in a high rate of breakage. The total milled rice recovery is 53%-55%, and head rice recovery accounts for 30% of the milled rice. The fine broken pieces are mixed with the bran and the ground rice hull, and used for the poorest and also as animal feed. The bran produced is left to the miller as the milling fee. This is most common type of mill at the village level seen in Nepal.

*Compact mill, two stage mills* – These are small capacity rice mills, with 0.5 to 1 ton per hour paddy output. They are also used for custom milling services in the rural areas. Milling recoveries are normally above 60% for this type of mill.

*Commercial mill* – The milling process in larger commercial mills combines a number of operations that produce white rice from paddy or rough rice. The process involves:

1. Pre-cleaning the paddy prior to milling;
2. Removing the husk or outer layer from the paddy;

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<sup>20</sup> More INFO: <http://www.knowledgebank.irri.org/rkb/grain-storage-systems/147.html> AND <http://www.grainpro.com/>

<sup>21</sup> <https://ag.purdue.edu/ipia/pics/Pages/home.aspx>

3. Polishing or whitening the brown rice to remove the bran layer;
4. Separating the broken grains from the whole kernels;
5. Bagging the milled rice; and
6. Managing the by-products.<sup>22</sup>

**Cleaning:** After milling, rice can be cleaned through hand-sorting. When paddy is milled in commercial rice mills, this step is included in the milling process.

**Consumption:** Nutrient losses can still occur during the food preparation process due to washing and cooking, but these losses depend on the type of rice. Parboiled rice has significantly lower levels of losses. Losses due to washing were reported to be a maximum of 3% while cooking nutrient losses were maximal 6%<sup>23</sup>. Losses in quantity can also occur during the cooking process with rice sticking to pots and becoming inedible.

## A.2 Current practices, associated losses, and recommended practices

**Table II. Current practices, losses, and recommended practices for rice**

Value chain step	Current practices	Losses	Recommended practices
<b>Field</b>	Cut the whole plant, harvest too late, since farmers already dry in the field	1-2%	Harvest 1 week prior to physiological maturity – use grain moisture tester, salt method
<b>Transport to threshing ground</b>	On head, in stacks on bullock carts, by hand	1-2%	Current practice okay
<b>On threshing ground</b>	Rice can be piled up to two months – due to labor shortage, sowing of other crops  Ground not covered with plastic sheet, which could facilitate exposure to fungal spores, since spores are soil-borne  Piles are exposed to insects, mice, birds, other animals	1-5%	Put plastic sheet/tarpaulin on the threshing ground. Turn paddy often and allow to dry  Thresh as soon as it is dry; need for rat control in threshing ground
<b>Threshing</b>	Threshing by hand, bullock, tractor; can result in damaged grains with resultant fungal infection	2-3%	Rice should have moisture content of <20%, threshing by machine
<b>Winnowing</b>	By hand using traditional method	1%	By hand winnower or machine-powered winnower or combine
<b>Drying</b>	No further drying; especially quality is affected	1-2%	Sun-drying or heated air drying

<sup>22</sup> [http://www.knowledgebank.irri.org/ericeproduction/PDF\\_&\\_Docs/Teaching\\_Manual\\_Rice\\_Milling.pdf](http://www.knowledgebank.irri.org/ericeproduction/PDF_&_Docs/Teaching_Manual_Rice_Milling.pdf)

<sup>23</sup> <http://www.fao.org/docrep/t0567e/t0567e0i.htm>

**Table II. Current practices, losses, and recommended practices for rice**

Value chain step	Current practices	Losses	Recommended practices
<b>Storage</b>	Storage in traditional container, have varied protection against pests – some more closed (mud), open (bamboo) Use of chemical (celphos), botanicals	2-10%	Storage in hermetic storage bags or metal bins; for protection against insects, AT LEAST USE plant based insecticides like neem, etc. – need for scientific evaluation of these substances
<b>Drying</b>	No further drying	0-3%	Drying from time to time, or keeping well-dried commodities in hermetic storage (bags)
<b>Milling</b>	In small scale mills (polish), high breakage of grains; huller mills 3 passages for coarse rice, 4 passages for fine rice <sup>24</sup>	0-2%	Use of sheller mill; reduces number of passages of grains – higher quality
<b>Cleaning</b>	Winnowing, sorting	1-2	In mechanized milling this is included in the milling process
<b>Consumption</b>	Rice sticks to pot while cooking	1-2	Use rice cooker, non-stick pot

### A.3 Main post harvest pests in rice

In Nepal, it was observed that infestation starts in the field or at least on the threshing ground. During the assignment, no standing rice was observed – all farmers had already harvested. Directly after harvesting, farmers with access to irrigation plant a second crop (primarily wheat), leaving paddy on the threshing ground for long periods perhaps averaging 15 days, in rare cases up to two months, just lying in a pile until they have time for threshing. Under the paddy piles, obvious burrows of mice and rats were seen, which reduced the quantity and quality (due to rat droppings) of rice. Furthermore, birds and livestock damage rice that is deposited in the threshing ground.

#### 3. Losses due to insects

Nepali farmers estimated losses due to insects in rice at 10%.

All the rice stocks inspected, stored and on threshing grounds, were infested by insects – mostly with the butterfly *Sitotroga* spp. and some with the weevil *Sitophilus* spp. Even paddy left on the threshing ground for drying was infested. In laboratory studies, rice infested with *Sitotroga* for six months usually resulted in losses of 10%<sup>25</sup> while rice infected with *Sitophilus* had higher losses of around 15%<sup>26</sup> and sometimes up to 20% after six months<sup>27</sup>. Field observations of rice stored for five to six months in a variety of containers showed that all of the household containers were heavily infested with a number of

<sup>24</sup> After industrial milling, 100 kg of paddy yields about 60 kg of white rice, 10 kg of broken grains, 10 kg of bran and flour, and 20 kg of hulls  
<sup>25</sup> L. Stengård Hansen; H. Skovgård; K. Hell 2004. Life Table Study of *Sitotroga cerealella* (Lepidoptera: Gelichiidae), a Strain from West Africa. Journal of Economic Entomology, 97: 1484-1490.

<sup>26</sup> Abdul Khaliq; Mansoor-ul-Hasan; Muhammad Sagheer; Khan, F. Z. A.; Gul, H. T.; Muhammad Asghar; Muhammad Yasir 2013. Varietal screening and development of rice weevil, *Sitophilus oryzae* (L.) in advanced rice genotypes at different temperatures. International Journal of Biosciences 3: 287-292.

<sup>27</sup> S. Subedi, Y. D. GC, R. B. Thapa and J. P. Rijal. Rice Weevil (*Sitophilus oryzae* L.) Host preference of selected stored grains in Chitwasn, Nepal. Center for Agriculture Research and Development, Bharatpur-12, Chitwan,

insects. Rice in storage bins can still be contaminated by mice, rice weevil, and *Sitotroga*. In some cases, when the bottom part of the store is made from wood or vegetable material, termites can also contaminate the rice and actually devour large parts.

#### **A.4 Main observed methods for pest control in stored rice**

Farmers use multiple means and methods to protect stored rice again post-harvest losses:

- Chemical pesticides: highly toxic celphos/phostoxin (Aluminium Phosphide) was found in all Agrovets visited and appears to be commonly used for insect control in farm HHs. Rice storage bins are often kept inside the habitation and even where people sleep; however, no precautions are being taken to ward off potential suffocation. CellPhos/PhosToxin is extremely dangerous and develops into a gas (phosphine gas) upon contact with the moisture. Pellets are being wrapped in paper or cloth to hold the tablet residue (aluminium phosphide) for it to be thrown away later. KISAN should not encourage its use.
- Natural products: a range of botanicals – neem, neem oil, Timur fruits (*Xanthoxylum armatum*, winged prickly ash), bojho roots (*Acorus calamus* L., sweet flag), and marich fruits (*Piper nigrum*, black pepper) – are being used. However, it is difficult to determine standardized application rates for these natural products. There is need for further research on application rate, efficacy, and toxicity. There is also need to formulate these products into marketable products that can be sold in Agrovet shops. Some Agrovets carried a variety of biological-based products produced in India that were marketed in Nepal, which were usually targeted at field pests. Testing their efficacy for the control of post-harvest insects should be encouraged if they might be effective against post-harvest pests.
- Raticide (zinc-phosphide) is being used to control rats. These are available in local markets at 10 NRs per package.

#### **A.5 Rice extension messages**

The NARC agricultural research station in Khajura has developed an extension leaflet in Nepali language that could be the basis of farmer training. This should be evaluated by the national post-harvest consultant for completeness and pertinence of the suggested practices. Furthermore, there are extension leaflets from other rice research institutions like IRRI<sup>28</sup>, WFP<sup>29</sup>, and FAO<sup>30</sup> that could be helpful in developing a post-harvest training program for KISAN.

#### **A.6 Recommendations on needed research and training for rice**

- I. The rice varieties recommended by GON and others have not been tested for resistance against post-harvest pests.

**Recommendations:** There is need to evaluate the post-harvest resistance of commonly recommended improved and or hybrid varieties. This could be done by NARC or

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<sup>28</sup> <http://www.knowledgebank.irri.org/postproductioncourse/default.htm> AND <http://www.knowledgebank.irri.org/rkb/index.php/storage>

<sup>29</sup> <http://www.wfp.org/content/p4p-training-manual-improving-grain-postharvest-handling-and-storage>

<sup>30</sup> <http://www.fao.org/docrep/x0039e/x0039e00.htm>

CSISA/CIMMYT in small scale participatory tests with a farmers group or as demonstrations with an individual farmer. Evaluation of such a trial should be done participatory in the field (see above), at harvest, during storage, at end of storage, and after preparation of the most common meal and consumption. At each evaluation, a ranking of the most favored variety and the reasons for it will be done.

This evaluation could also be done by researchers in the lab, testing susceptibility of rice varieties to post-harvest pest similar to the protocols elaborated by Chougourou et al. 2013<sup>31</sup>. However, farmers' opinions will not feed into results if this approach is used.

2. Almost all farmers were harvesting late and leaving rice in piles in the threshing ground which leads to high losses and negatively impacts the quality and storability of rice.

**Recommendations:** Inform farmers and other stakeholders in the value chain of the negative impact of the current practices on grain quality. Include this in a training course on good post-harvest practices.

More significant gains in quality improvement of the end-product can be made by mechanizing harvesting and the post-harvest threshing and drying process. This will also significantly reduce post-harvest losses.

3. There were high losses observed at threshing, either manually or even with machines, through grain scattering and keeping panicles in piles on the threshing ground.

**Recommendations:** Farmers should cover the threshing ground with plastic tarpaulin to reduce losses of paddy grains. Where possible threshing should be mechanized and combined with drying. Threshing service providers should be connected to the KISAN farmer groups. Introduction of mechanized threshing, which is widespread in the Terai, also has the potential to reduce drudgery for women farmers. Technology options include pedal drum, and axial-flow (combine) threshers. These will likely have different niches depending on farm size and the existing degree of mechanization.

4. Farmers do not determine grain moisture content prior to storage.

**Recommendations:** There is need to ensure that rice is stored with a moisture content of less than 14% in order to avoid significant quality deterioration. Storing high moisture grain can result in low germination if used as seed and fungal infection which can lead to mycotoxin contamination. Farmers need to understand the importance of proper drying for obtaining good quality grains. There are a number of drying technologies available in the subregion. Agrovets, LSPs, or other entrepreneurial villagers could offer moisture testing to farmers for a fee and drying services to farmers<sup>32</sup>.

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<sup>31</sup>Chougourou, D. C., Togola, A., Nwilene, F. E., Adeliassi, J., Bachabi, F., & Oyetunji, O. E. (2013). Susceptibility of some Rice Varieties to the Lesser Grain Borer, *Rhyzopertha dominica* Fab. (Coleoptera: Bostrichidae) in Benin. *Journal of Applied Sciences*, 13(1).

<sup>32</sup> <http://www.grainpro.com/?page=grainpro-solar-bubble-dryer>

In a wider context, good grain quality does not command a higher price. In fact, in Nepal, usually only slight deductions, if any, are being made when products do not meet the purchasing specifications. Local rice millers purchase indiscriminately, lack specific standards, and do not remunerate for good quality.

5. Rats lead to high levels of damage in rice deposited in the threshing ground and in storage.

**Recommendations:** There is need for good sanitation and hygiene in the store, in the house, the surrounding area, and on the threshing ground. Stores need to be rat-proofed to make access to the store impossible by eliminating openings, cracks, and fissures. On open stores, rat guards can be installed at least 120cm off the ground. Traps can be used to capture rats (cage trap, sticky trap). Cats can be used to control rats, but they have also been found to create other problems like defecation in stored grains. The GON recommends zinc phosphide for rat control, but this product also has serious risks for untrained users due to its high toxicity. KISAN should not recommend this product and should inform farmers of the dangers of using this product.

6. Storage containers do not protect the stored rice paddy sufficiently.

**Recommendations:** There is need to test the proposed improvements of local storage containers (section A.7) in participatory tests with farmers to identify efficient technologies.

Local hermetically sealable plastic storage bags (need to be high density poly ethylene HDPE plastic bags that are about 80 microns thick), inside a woven polypropylene bag (WBE), need to be tested. Experimental set-up should be Grain-Pro bags, PICS-Bags (double bagged + outer WBE), PICS-Bags (single bagged + outer WBE), and simple WBE bags with rice paddy stored in them. Then there should be monthly participatory evaluation. This trial can be done with farmers' paddy in their storage rooms, with an undertaking that will compensate them in case of losses. The only system where losses will be expected is the traditional storage system.

Metallic storage silos also offer good protection. Most likely, more local metal smiths need to be trained in this technology with the help of the available training guides<sup>33</sup>. It may be possible to provide and air tight seal for the bins.

7. Paddy stored in mud stores had a reasonable quality and perhaps lower pest infestation than in other types of stores at the time of the mission. In most stores, farmers used botanicals like neem etc. to control insects. These stores are not mice, rat or termite proof. But where well build offer reasonable protection.

**Recommendations:** The mud stores (Dehari) could be promoted. It could be possible for certain master craftsmen to become service providers for the construction of such stores. The downside is that these stores need to be resurfaced and cleaned about once per year and are susceptible to rat and termite infestation.

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<sup>33</sup> <http://www.fao.org/fileadmin/templates/inpho/documents/ae616e.pdf>

8. Paddy rice showed high levels of insect infestation.

**Recommendations:** Most farmers do not use insecticides on paddy, but the high levels of infestation showed the need for some form of pest control. There is a wide range of plants that can be used to control insect pests, which are known to some farmers and research institutions. There is need to collect more detailed information on the effective plant-based insecticides (plant part used, application rate, efficacy, period of efficacy) and their application rate. Eventually, private sector entities should be encouraged to formulate these into ready-to-use product using local production systems.

Farmers should be aware of 1) insect biology such as egg, larva/pupa, hibernation, and multiplication and 2) disease cycle. This should be incorporated into a training course on insect control including proper pest control measures.

9. There is no price differential for good quality paddy.

**Recommendations:** To incentivize production of good quality grain, there needs to be a public dialogue to enforce a price differential for good quality rice and inform consumers about the risks of consuming poor quality and benefits of good quality. Also, the national rice standards for fine rice and parboiled rice need to be advertised. A number of interrelated features determine the quality of paddy. These features are moisture content, purity, varietal purity, cracked grains, immature grains, damaged grains, and discolored/fermented grains. These characteristics are determined by the weather conditions during production, crop production practices, soil conditions, harvesting, and post-harvest practices.

10. All Agrovets visited are selling highly toxic celphos/phostoxin; many farm HHs are using celphos/phostoxin. GON recommends this product to eliminate insects in stored grain, Due to its high toxicity KISAN does not recommend its use.

**Recommendations:** All stakeholders should be informed about the risk of using this highly toxic product including their documented use for suicide in India and Nepal and other cases of poisoning. Farmers need to clearly understand that use of celphos is only for one-time disinfestations and that there are no long-term effects of this insecticide. More information on this product and the safety precautions to take during its application can be found in KISAN's PERSUAP and at <http://www.rentokil.co.uk/commercial-pest-control/pest-control-products-for-professional-use/phostoxin-mole-rabbit-and-rat-control/health-and-safety-phostoxin/index.html>. This information emphasizes that training should be provided on the use of hermetic storage bags and metal bins.

11. Farmers and traders do not have adequate knowledge for proper post-harvest handling of rice.

**Recommendations:** A training module on proper paddy drying, determining moisture content, and maintaining the dried product quality in storage should be designed and included in KISAN's training agenda.

12. Farmers are not knowledgeable about the benefits of hermetic storage bags.

**Recommendations:** NARC and others are recommending the use of GRAIN Pro superbags. The project could work with them or others to produce a small extension leaflet in local language, explaining the use of, correct tying technique, and benefits of hermetic storage bags similar to the leaflets developed by the PICS project in West Africa. Demonstration trials and village and market open-bag ceremonies should be included in the testing and dissemination of such bags. Additionally, the “candling technique” for making the metal bin or other stores airtight should be demonstrated. You put a candle in a nearly full bin, light it and seal the bin. The candle uses the remaining oxygen.

### 13. Farmers are not exploiting the benefits of community stores and grouped sales.

**Recommendations:** It may be possible to help farmer groups to construct community stores or possibly work with millers. These stores might be linked to a microcredit system with the stored crops acting as collateral. Further economies of scale could be exploited on the basis of group sales to millers or other larger entities that would need large quantities. Farmers are forced to sell produce right after harvest to generate needed income.

**Recommendations:** It is possible to implement warehouse receipt<sup>34</sup> or inventory credit system<sup>35</sup> for receiving credit from a miller, bank, or microfinance institution on the basis of depositing grain bags as collateral. These bags will be sold at a later date when market prices are higher. But there is need for good storage management for such systems to be effective.

## B. MAIZE

Maize is the second most important crop in Nepal after rice. It is cultivated in 824,525 hectares with a total production as about 1,484,112 metric tons. About 20% of the caloric needs of Nepali populations are covered through maize consumption. Its average productivity is 2,200 kilograms per hectare. The team visited farmers who were reasonably close to roads and therefore close to markets. Of those observations, about 10% of the crop is being consumed or sold as green maize prior to harvest. During sorting, prior to storage of the good cobs, about 15%-20% is sorted out, since they are too small for storage. Up to 40% of the harvested maize is sold right after harvest to generate income. About 50% of the produced maize will be stored to serve as food for the household.

### B.1 Description of observed post-harvest systems

**Varieties:** Most of the officially released seed varieties are open pollinating varieties (OPV) with only one hybrid variety released over the last year. Lately, the GON has made efforts to increase the number of commercial hybrid maize varieties in Nepal by allowing entry of new varieties. More than 30 hybrid maize varieties have been approved for use in Nepal.<sup>36</sup>

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**Table III. List of released OPV in Nepal**

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<sup>34</sup> [http://www.ruralfinance.org/fileadmin/templates/rflc/documents/Review\\_of\\_Warehouse\\_pdf.pdf](http://www.ruralfinance.org/fileadmin/templates/rflc/documents/Review_of_Warehouse_pdf.pdf)

<sup>35</sup> <http://www.fao.org/docrep/v7470e/v7470e00.htm>

<sup>36</sup> <http://www.thehimalayantimes.com/fullNews.php?headline=Govt+plans+to+introduce+hybrid+seeds&NewsID=401066>

Released Varieties	Pipeline Varieties
Manakamana-3 (2002)	Across-9942/Across-9944
Deuti (2006)	(2) Arun-4 (EV)
Shitala (2006)	Arun-I (EV)
Manakamana-4 (2008)	Pool 17 (EV)
Manakamana-5	S99TLYQ-B (Yellow QPM)
Manakamana-6	CorralejoS99SIWQ (QPM)
QPM- Poshilo Makai- I (2008)	CelayaS91SIWQ (QPM)

Most farmers stated that they use improved OPVs, often obtaining it from other farmers but do not replace the seed every three years as recommended by the Department of Agriculture (DOA). Seed replacement rates in maize are about 9-11% in Nepal. Overall, yields are low and there is need to have better agronomic practices and appropriate varieties to significantly increase productivity and reduce post-harvest losses.

**Harvesting:** Maize is dried on the stalk until farmers feel it is dry enough for harvesting. In general, the crop is physiologically mature seven to eight weeks after flowering. At that time, the kernel contains 35%-40% of moisture and has the maximum content of dry matter. At this time the crop should be harvested in order to avoid unnecessary losses in the field<sup>37</sup>. Late harvesting will lead to high insect infestation and low quality of grains.

The physiological maturity in maize is recognized by the following characteristics:

- Yellowing of most of the leaves;
- Some of the leaves start drying up;
- Yellowing and drying up of the husks, husks turning papery;
- Maize grains acquire a glossy surface;
- The grain is too hard and uncomfortable to chew when it is roasted for eating; and
- Some maize cobs begin to droop (hanging downward) on the stalk.

The maize plant is harvested by hand – either the whole cob is picked with the husk, or the whole plant is cut at 30-50cm from the ground. The stalk is used as animal fodder. Nearly 50% of the cobs are not stored and are sold, consumed, or sorted out to be fed to animals right after the harvest. A large share of the maize harvest is used to feed cattle.

**Transport:** Maize is transported by hand on the head or in *dokos* to the homestead – since most of the farmers live in the hills and farms HHs are some ways away from the agricultural fields and there are few roads. Some useful transport technologies recommended for on-farm use in the Terai include:

<sup>37</sup> [http://www.fao.org/fileadmin/user\\_upload/inpho/docs/Post\\_Harvest\\_Compendium\\_-\\_MAIZE.pdf](http://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_Compendium_-_MAIZE.pdf)

- Hand pushed wheel barrows and carts, usually made by women;
- Pack-animal, particularly donkey and mules; and
- Draught animals to carry crop-loads on sledge and on carts.

**Drying:** The main purpose of drying is to prevent germination, prevent the growth of bacteria and fungi, and considerably slow the development of mites and insects. None of the questioned farmers said that they practiced drying of maize cobs prior to storage but in other parts of Nepal drying does occur.



Figure 6: Storage of maize under roof



Figure 5: Maize storage in thankro

The most common maize storage systems in Nepal are essentially drying frames. Drying prior to storage is not necessary if cobs are stored in such systems. If farmers revert to storage systems where maize cobs are harvested, de-grained, and then stored as grains in bags, drying would be one of the essential steps to maintain post-harvest quality. There are different drying systems for maize cobs. Removing the husk would facilitate drying, but will simultaneously remove some protection against insect infestation.

Drying systems for grains that could be implemented in Nepal are:

- Drying on mats;
- Drying on plastic sheets, either clear or black;
- Concrete drying floor; and
- Drying cribs.

**Sorting:** Maize cobs are sorted out to select those that are well suited for storage. Cobs that are small in size, have insect damaged grains, are deformed, have incomplete husk cover, and/or are otherwise defective are set aside prior to storage. Some farmers in Nepal also reduce the number of husk-leaves to facilitate the drying process while in storage.

**Storage:** Storage of maize should protect it from environmental effects and pests. None of the observed storage systems in Nepal is providing adequate protection. Almost all of the hill maize cobs were stored on the *thankro*, an open drying frame. Some maize was said to be stored in mud-stores, *Daheri*, and polypropylene bags as grains (the team did not observe this during this assignment).

- Farmers and the consultant observed that hybrid maize varieties were more susceptible to insects than local varieties. Even CIMMYT observed this for their released varieties<sup>38</sup>. All the farmers visited stated that they use local maize varieties to reduce post-harvest losses and prefer white maize for consumption. There is need to include susceptibility to post-harvest insects as one of the evaluation criteria for the selection of new maize varieties.
- Maize is stored with the husk, or with some husk-leaves removed, mostly in traditional stores *thakro* attached to poles, attached to trees, under the house eaves, under the roof eaves, in piles on floor, or over the kitchen (especially for seed storage).
- The team observed that stored quantities of grains were quite low – rough estimates show that a farming family would store less than 0.5 tons of maize cobs, at least the observed farmers in the hills. This matches roughly with data that was found in [http://neksap.org.np/uploaded/FS%20Bulletin%2039\\_English.pdf](http://neksap.org.np/uploaded/FS%20Bulletin%2039_English.pdf).
- Most corn storage gives no protection for cobs against the rain, unless cobs are placed under a roof. The thatch roof that is placed on the *thakro* gives little protection against rain, and will even provide a very good microclimate for fungal development. Local practices could be improved by placing large metal or plastic roofs well above the stored cobs, leaving space for good aeration.
- It was observed at almost all farms visited that the top two layers of cobs in open stores were infected with fungi – mostly *Fusarium*, *Alternaria*, and *Penicillium*, but some cobs were found to be infested with *Aspergillus* spp., the causal agent of aflatoxin. Not all fungal infection will necessarily lead to mycotoxin contamination, since mycotoxin development is highly variable and dependent on environmental conditions and fungal strain (not family, but within a family there are strains which are more or less toxic).
- The team observed that some cobs were already infested with weevils (after two months storage) – *Sitophilus*, spp. In one farmer's store, cobs were infested with the most damaging quarantine pest, the Khapra beetle (*Trogoderma granarium*), a species that will lead to losses of 30% and higher. None of the farmers said that they used insecticides to control pests.
- It was noted that no separate grain storage was practiced for storing maize seeds that are used for planting the next crop. These seeds are usually taken from the stored cobs on the drying racks, by selecting cobs that are found to have the right grain characteristics. Storage of seeds in glass bottles, earthen closed canaries, or airtight bags are good systems for maintaining seed quality.

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<sup>38</sup>[http://cropwatch.unl.edu/c/document\\_library/get\\_file?uuid=a412f96d-7f83-437a-9a10-d47c19ed3a21&groupId=4362157](http://cropwatch.unl.edu/c/document_library/get_file?uuid=a412f96d-7f83-437a-9a10-d47c19ed3a21&groupId=4362157)

**De-husking and shelling:** Maize is de-husked by hand; shelling is either done by hand or by beating the cobs in bags with sticks to loosen the grains. Beating with sticks will damage the grains and leave entry points for fungal spores.

There are several devices to facilitate shelling:

- Hand-held devices of various designs and outputs;
- Small rotary hand sheller (see figure 7);
- Free standing, manually operated shellers; and
- Electric or PTO powered shellers.



Figure 7: Hand sheller

**Drying grains:** Farmers stated that grains are rarely dried after shelling since cobs have already been sufficiently dried on the *thakro* and in other stores. Maize grains are rarely stored for a long time in Nepal. Drying is one of the key steps for maintaining quality of maize. There are multiple systems of mechanized dryers that are available and are described in the rice section.

**Milling:** Traditionally maize cobs are ground to flour at the HH level using stone mills. In the hills, stone mills are often powered by water or by hand, but in areas with electricity village-based electric mills are used to grind corn into flour. At milling losses can be a maximum of 5%.

## B.2 Current practices, associated losses, and recommended practices for maize

**Table IV. Current practices, losses, and recommended practices for Maize**

Value chain step	Current practices	Losses	Recommended practices
<b>At harvest</b>	10% consumed as green maize or sold		
<b>Field</b>	Collect the cobs, cut the plant, harvest too late, since they already dry in the field	3% cobs left in field; +3% fungi	Should cut leaves or upper part of plant to facilitate drying of cobs  Harvest at physiological maturity – use method to determine grain moisture, grain moisture tester
<b>Transport</b>	On head or in <i>dhokos</i>	1%	
<b>Sorting</b>	Sort out small, damaged, and fungal damaged cobs; sale of cobs prior to storage 40%	3-10%	Good practice – final amount to be stored is reduced
<b>Drying</b>	No further drying	1%	Use cemented drying floors or flat-bed dryers to dry to <14% (grain moisture tester)
<b>Storage</b>	Storage in traditional container, have varied	5-30%	Take off cobs from <i>thakro</i> before rains start

**Table IV. Current practices, losses, and recommended practices for Maize**

Value chain step	Current practices	Losses	Recommended practices
	protection against pests – some more closed (mud), open (bamboo)  Some farmers reduce the number of husk leaves to improve drying		(February/March)  Storage as grains in hermetic storage bags; metal bins (after 4 months of storage on drying rack – shell and store as grains)  Use botanicals in simple reusable bags for insect control; botanicals could also be attached to side of store they are proven repellants
<b>Shelling</b>	Shelling (by stick, by hand); grains are damaged and cracks can be entry doors for fungi	3%; +5% fungi	Use machine powered sheller; small scale manual shellers
<b>Drying</b>	No further drying	-	Drying from time to time as grains, on mats or on plastic
<b>Cleaning, sorting</b>	Winnowing (debris), sorting (discolored, insect infested grains)	3-5%	
<b>Milling</b>	Ground into flour, take to mill	3-5%	
<b>Consumption</b>	Maintain low moisture in already milled flour, consume rapidly	-	Shelf-life 4-6 weeks under high temp, and humidity condition

### B.3 Main pests in maize

The team observed that infestation of maize with post-harvest insects starts in the field, since freshly harvested cobs already showed signs of insect infestation and live individuals could be observed. The most damaging pest was *Sitophilus* spp. on maize cobs in Nepal.

#### 4. Losses due to insects

Nepali farmers estimated losses due to insects in maize at 15 to 20%



Figure 9: *Sitophilus* spp. on maize cobs



Figure 8: Fungal damage on maize cobs (*Fusarium* & *Alternaria* spp)

*Sitophilus* can lead to losses of between 15% and 20% in stored maize cobs after three months of storage. More importantly, these species provide the entry holes for other pests like *Rhyzopertha dominica*, *Tribolium castaneum*, and *Oryzaephilus surinamensis*. Furthermore the lepidopteran pest *Sitotroga cerealella* and *Plodia interpunctella* can be a problem in maize in Nepal<sup>39</sup>.

#### B.4 Main observed methods for pest control in maize

Most hill maize is stored on open drying racks or under household roof overhangs. Little if any is currently shelled and stored in other structures. Shelling usually takes place immediately before consumption. Farm HHs generally do not take any steps to control insect or even rodent pests in maize.

- Chemical pesticides: Celphos/Phostoxin (Aluminum phosphide) is used by farmers in mud bins with no knowledge about its potential hazard, its mechanism of action, its period of efficacy, or conditions for use. But apparently, it is not widely used in maize.
- A very few farmers were using natural products such as neem, neem oil, Timur (*Xanthoxylum armatum*), bojho (*Acorus calamus* L.); recipes for these plant-based products were not standardized and efficiency was judged to be lower than chemical insecticides.
- Most maize farmers had little knowledge about plants they can use to protect their stored cobs against insect pests. The ecology of several plants that are used in West Africa was observed (*Ageratum conyzoides*; *Ocimum gratissimum ramtuli* [रामतुलसी]; lemon grass) – these could be tested and their effectiveness evaluated. The objective should be to formulate commercial products, potentially with small scale enterprises emerging that could formulate and sell such products similar to the model in West Africa<sup>40</sup>.

#### B.5 Recommendations on needed research and training for maize

- I. The maize varieties seen during this study do not appear to have good resistance against post-harvest pests.

<sup>39</sup> [http://www.fao.org/docrep/x5048e/x5048E12.htm#Farm level grain storage pest management in Nepal](http://www.fao.org/docrep/x5048e/x5048E12.htm#Farm%20level%20grain%20storage%20pest%20management%20in%20Nepal)

<sup>40</sup> Biophyto Collines, Glazoue, Benin. Contact : +229 95 71 92 08; zodomegildas@yahoo.fr

**Recommendations:** There is need to evaluate pest resistance of the most common improved/hybrid maize varieties against the most common local maize varieties to test their resistance towards post-harvest pests. These tests can be done as participatory trials evaluating the most common hybrid varieties, with open pollinated varieties (OPVs) and local varieties with farmer groups. Varietal tests can also be done in small scale laboratory trials led by researchers evaluating the resistance of maize varieties.

2. Farmers keep their maize in the same storage structure without considering how long it will be there or the fact that the environment is changing.

**Recommendations:** Farmers need to plan maize storage. Different stores should be used for: short-term storage (three to five months) in *thankro* or local open stores *daheri*; for season-long storage (six to nine months) maize should be shelled and stored in mud stores, hermetic storage bags, or metal silos; and long-term storage (greater than nine months) by ensuring correct harvesting, drying, and storage of shelled grains in hermetic storage bags or metal silos. Farmers do need select cobs for future use as seed, and dry and store that maize appropriately.

3. The existing storage structures do not provide sufficient protection to maize cobs.

**Recommendations:** There is need to test improvements to the storage structures (adding roofs or covering the maize with plastic, protection against humidity) and if shelled then new types of containers such as hermetic storage bags and metal silos. Different types of hermetic storage bags should be tested for maize such as Grain Pro, single PICS bags, double PICS bags, and normal polypropylene bags. These bags are becoming available in Nepal but are too costly (due to high tax rates) but there is need to test them in varying climatic regions.

4. Metal silos are being used, primarily for seed storage, without making them airtight.

**Recommendations:** If longer term storage is to be used, introduce the candling technique to draw out oxygen from stored grains prior to closing the metal silo. A candle is lit inside the stored maize grain and then the store is closed with the lid. The candle will use up all the oxygen in the silo and stop burning when the oxygen is depleted.

5. Farmers rarely use insecticides to control postharvest insects.

**Recommendations:** There is need to source for safer products that can be used to control insects of stored food. Research institutions should be encouraged to study insecticidal plants which could be effective in controlling post-harvest pests including application rate, efficacy, and application method. Such research could be based on farmers' knowledge of insecticidal plants. The long-term aim should be to formulate ready-to-use product. KISAN should promote integrated pest management solutions and follow the recommendations of the PERSUAP.

6. Maize cobs are dried in the field resulting in high post-harvest losses.

**Recommendations:** There is need to train farmers on how to dry properly, determine moisture content, and maintain the quality of dried products such as how to keep out moisture and control moisture seepage. KISAN should approach IRRI/Grain Pro or others, which are

developing/testing bubble dryers, mainly for rice currently. See <http://www.knowledgebank.irri.org/rkb/examples-of-dryers/solar-bubble-dryer-beta-version.html> and <http://www.grainpro.com/?page=grainpro-solar-bubble-dryer>

7. Current post-harvest systems lead to high losses due to pest infestation and fungal infection.

**Recommendations:** It is suggested that maize be dried on the thankro for two to four months, shelled and transferred to bags or containers. Train farmers on improved storage and pest control, methods for keeping fungi levels down such as practicing integrated post-harvest management. KISAN should train farmers on the use of hermetic storage bags (which will be available in the country soon) and the correct tying of such bags. The NARC agricultural research station in Rampur has developed an extension leaflet in Nepali language that could be the basis of farmer training. Furthermore, there are extension leaflets from other rice research institutions like CIMMYT and FAO that could be helpful in developing a training program for KISAN.

8. On many of the maize cobs, fungal infection and mold were observed.

**Recommendations:** There is a need to obtain a clearer picture of mycotoxins risk (aflatoxin and fumonisin) in Nepal – e.g. levels, prevalence, risk factors. There is some capacity to study mycotoxins in NARC and very soon in DFTQC, which could be used to gain better insights. KISAN, while not in a position to be directly involved in this area, might encourage involvement by international research institutions such as CIMMYT, ICRISAT, or others in mycotoxin research in Nepal.

9. Different shelling methods are being used.

**Recommendations:** There is need to test post-harvest quality after shelling (manual, hand, mechanical – different models). There have been reports that some shellers lead to higher mycotoxin contamination<sup>41</sup>.

10. Few hill farmers are making good profits from their summer maize crop which is primarily a subsistence crop, as opposed to winter or spring maize which are often hybrids grown in the terai as commercial crops.

**Recommendations:** There may be some potential to train farmers on group marketing and other methods on how to raise their profits like an inventory credit system. Farmers could also wait for higher prices prior to selling their crop to increase their profit. However, this means farmers would have to maintain their crop quality for longer.

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<sup>41</sup> Fandohan, P., Ahouansou, R., Houssou, P., Hell, K., Marasas, W.F.O. and Wingfield, M.J. (2006) Im-pact of mechanical shelling and dehulling on Fusarium infection and fumonisin contamination in maize. Food Additives and Contaminants 23, 451-421.

## C. LENTILS

### C1. Description of observed post-harvest system

Lentils are mainly grown in the lowland Terai region of Nepal in rotation with cereals based on the availability of residual soil moisture after rice is harvested. Lentils are generally planted in mid-October to November and harvested in March and April. Nepal produced 208,201 metric tons of lentils in 2011 on 207,630 ha, with about 700,000 farm households involved in production. Average yield is 1.01 t/ha. According to the USAID Lentil Value chain study<sup>42</sup>, farmers keep about 30% of their product for home consumption and the remaining quantity is sold in the market. About 65% of lentil is sold to small scale collectors known as Baniyan, 15% to district level wholesalers/millers, 10% to commission agents, and the remaining 5% to large collectors known as *gallawallas*.

During the assignment, the team observed that farmers' remaining quantities stored in their households were very low, since we visited the farmers at the beginning of the lentil planting season. Farmers mostly kept lentils in recycled containers, primarily plastic containers (small quantity, see Figure 10), metal drums/ghee container, clay pots and small *daheri* (see Figure 11).

**Varieties:** The common variety grown in Nepal is Masoor – it has brown skin and is orange inside. New improved varieties (Khajura 1, Khajura 2, Simal, and Sikhar) are available for whole Terai and central hill regions. Potential yields of new varieties in these areas are higher than the national average yield. There have been some recent introductions of new varieties from ICARDA Maheshwor Bharati and Sagun.

**Harvesting:** Early cultivars are ready to harvest in 80-110 days, while late cultivars reach maturity in 125-135 days. Harvesting should start when the bottom pods of the lentil plants turn from yellow to brown, and the seeds rattle within them when shaken. At this time, the upper pods will still be green, but further delay will increase the risk of harvest loss due to shattering of the bottom pods. Pull the entire plant out of the ground by grasping the main stalk and rocking it back and forth in the soil until it loosens from the ground.

**Drying:** Lentil plants are dried in large piles in the field until collected for threshing. During this drying period, there is the risk of pod shattering with seeds being lost. The drying process should take one to two weeks, depending on the weather.

**Transport to the threshing ground:** Transport to the threshing ground is either by foot or with bullock-cart or tractor, with the latter being less labor intensive.

**Threshing:** The piles are then collected and taken to a central threshing facility. Threshing of lentils should be done when they

### 5. Lentil Loss

Nepali farmers estimated losses in lentils at 10%.



Figure 10. Recycled plastic containers for lentil storage

<sup>42</sup> <http://nepaltrade.org/sites/default/files/reports/Value-Chain-Market-Analysis-of-the-Lentil-Sub-Sector-in-Nepal.pdf>

have a moisture content of less than 20%, otherwise the grains are squashed. Ideally, the seed should be threshed at about 16% moisture. This will result in a cleaner crop and a reduction in shattering losses and seed damage. Threshing is usually done by animals and animal-drawn disks, which continually pass over the piles of plants until the seeds are separated from the pods. There are many simple threshing machines, both manual and mechanized, that can be used to thresh lentils.

**Winnowing:** The threshed material is winnowed to separate the seeds from the straw and other plant debris. The residues from winnowing are valued as feed for livestock and often command a price equal to or greater than that of the seeds.

**Storage:** Lentil seed coats turn brown with age, resulting in a reduction in grade. The browning is a result of the oxidation of tannin precursors in the seed coat, and occurs faster at high temperature, high humidity, and in sunlight. For this reason, it is advisable to store lentil seeds in light-tight bins. In Nepal, farmers store in recycled plastic containers, in mud stores *Daheri*, in smaller and mud jars. Some of the farmers stated that they rub the grains with mustard oil to protect them against weevils.

**Sorting and sieving:** Harvested grains (threshed/shelled/dried) need further processing to get rid of various types of contaminations or undesirable matter, such as inert material, seeds of noxious weeds, other crop/variety seed, decorticated seed, damaged seed, and/or off-size seed. Cleaning and grading result in reduced bulk of the material, high-value products, safe and longer storage, and more out-turn of a better quality milled products.



Figure 11. *Daheri*

**Milling:** Pulses are usually converted into dhal by decutlating (removing the outer layer) and splitting. Both dry and wet milling processes are employed. By and large, carborundum emery rollers are used for dehusking and burr grinders for splitting. Decuticling is seldom complete in single pass requiring multiple passes, each pass producing 1.5% to 2% fines reducing recovery of dhal.

Basic processes in dhal milling are cleaning, dehusking, splitting, separating, and bagging. Major variation is involved with dehusking process only. Lentils are difficult to dehusk – as a result repeated operations by dehusking rollers are required. Rewetting and drying is done to loosen portions of husk sticking after repeated rolling. The removal of the outer husk and splitting the grain into two equal halves is known as milling of pulses. To facilitate dehusking and splitting of pulses, alternate wetting and drying method is used. Yield of split and pulses in traditional mills are only 65% to 75% due to the above losses compared to 82% to 85% potential yield.

## C.2 Current practices, associated losses, and recommended practices for lentils

**Table V. Current practices, losses, and recommended practices for Lentils**

Value chain	Current practices	Losses	Recommended practices
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step			
<b>Field/harvesting</b>	Uproot or cut the whole plant	1%	No change required
<b>Field drying</b>	Plants are dried in large piles	1-5%	Dry on tarpaulin to reduce grain losses
<b>Handling</b>	By hand	1%	No change required
<b>Threshing</b>	Beating with sticks, mostly sold right after threshing	1-2%	With mechanical threshers, on tarpaulin
<b>Winnowing</b>	By hand	1%	Manual or mechanical winnowers, sorting (small, infested, other grains)
<b>Transport</b>	In bags	1-4%	No change required
<b>Drying</b>	No drying		Sun-drying, on black tarpaulin; use moisture meter
<b>Storage</b>	Store in recycled containers, no large scale storage, no further protection against insects	Up to 30%	Store in hermetic storage bags, closed containers, clay pots, metal bins Use insect and rat control practices
<b>Sorting, cleaning,</b>	Manual sorting, sieves	7-8%	Color sorters, grading sieves
<b>Milling - taking off outer layer</b>	Stone mill	Husk <15% losses <13%	Improved mills

### C.3 Main pests in lentils

Lentils could be attacked by bruchids – but no insect infestation was observed during the mission. According to the literature, the most serious and frequently encountered insect pests of the stored lentils are *Bruchus ervi* and *B. lentis* with *Callosobruchus chinensis* and *C. maculatus* also widespread. These can lead to losses of up to 30% under serious infestation<sup>43</sup>. During the visit, the team did not observe any visible insect infestation or damage, but most of the stocks looked very dusty. One batch of lentils showed caking, which may be a sign of fungal infection. There have been previous reports of mycotoxin in lentils from Egypt and Sudan with low levels of toxin.

### C.4 Main observed methods for pest control in lentils

Some farmers said that they coated beans with oil to protect them against insect infestation. None of the lentils showed presence of insects. It is well known that oils can protect grains against insect

<sup>43</sup> Stevenson, Philip C., M. K. Dhillon, H. C. Sharma, and Mustapha El Bouhssini. "Insect pests of lentil and their management." In *Lentil*, pp. 331-348. Springer Netherlands, 2007. [http://link.springer.com/chapter/10.1007%2F978-1-4020-6313-8\\_20#page-1](http://link.springer.com/chapter/10.1007%2F978-1-4020-6313-8_20#page-1)

infestation. A vast number of edible oils (mustard, groundnut, coconut, castor, sunflower, safflower, sesame, and cotton seed) and non-edible oils (neem) have been tested. Additionally, seeds can be mixed with ash or sand to protect them against insects. A vast amount of insecticidal substances that have been tested for their efficacy against bruchids exist<sup>44</sup>. Solarization can be used to kill insect infestation on already infested seeds. Seeds are spread on a black plastic sheet and covered with another sheet, and then the grains are exposed to sunlight to high temperature (65°C) in the solar heater for two hours.<sup>45</sup>

### C.5 Recommendations on needed research and training for lentils

1. Lentil prices increase significantly during the season (up to 30% price differential).

**Recommendations:** If farmers store the pulse for six months, they can significantly increase their income. Lentils can be safely stored in hermetic bags, hermetic plastic containers, metal drums, or metal silos. For added protection, a vegetable oil can be added for insect control.

2. Vegetable oils can be used to control insect infestation.

**Recommendations:** There is need to review the literature to determine types of oils used, effective dosages, and period of efficacy prior to testing of locally available oils in farmer participatory tests for lentil storage.

3. During the survey the team observed caking in lentils, which is a sign of moisture influx and potentially fungal contamination.

**Recommendations:** Farmers should be informed about the benefit of sun-drying and solarization for maintaining quality of their lentils. Also, hermetic storage bags will safeguard stored lentils.

4. A high percentage of impurity in lentils was observed.

**Recommendations:** Many of the lentils sold in the market were not pure. If cleaned and sorted, farmers could capture a higher price for their lentils. Sieves or hand sorting could be used to sort out foreign matter, weed seeds, and seeds from other crops.

Farmers need training on improved storage and pest control. In particular, training on the use of hermetic storage bags would be useful to maintain lentil quality in storage.

5. Lentils sold in the Nepali market are of very low quality and might not meet export standards.

**Recommendations:** Farmers and traders need training on meeting the market demand and on quality requirements for the different (local, regional) and how to improve quality through sorting.

6. Producers sell immediately after harvest without waiting for higher prices.

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<sup>44</sup> <http://www.insectscience.org/6.03/>

<sup>45</sup> Murdock, L.L., Shade, R.E., 1991. Eradication of cowpea weevil (Coleoptera: Bruchidae) in cowpeas by solar heating. *American Entomologist* 37, 228-231.

**Recommendations:** Farmers need training on group marketing and methods for raising their profits. Lentil producers work as individuals rather than as a large group which restricts their bargaining power when dealing with collectors. Large scale collectors and exporters dominate the value chain by holding large quantities of lentils in their storage facilities until the market price fluctuates to a rate that suits them. If farmers had better tools for maintaining post-harvest quality and reducing losses they might be less tempted to sell right after harvest. Having safe storage containers such as hermetic storage bags will reduce the risk of long-term lentil storage and give incentives to farmers to wait for better prices.

## D. SUGGESTED IMPROVEMENTS IN STORAGE CONTAINERS FOR CEREALS AND GRAIN LEGUMES

The existing structures do not provide sufficient security to stored grains against insects, rodents, and birds. Therefore, some efforts can be made to improve these structures, but these changes need further in-depth studies to identify culturally acceptable solutions.

1. Lifting stored cobs higher off the ground (at least 120 cm), and rat-proofing stores especially through the construction of rat guards. Improvement in *thakro* by upgrading thatch/tin/plastic roofing and cover cobs with nylon netting or plastic to ward off rain.
2. Sandwiching polythene between two layers of mud-bins (*Dehari*) to ward off moisture seepage.
3. Cement plastering on mud-bins (*Dehari/Kothi*) from outside, to control moisture influx.
4. Use oil-paint or bitumen/tar to paint mud-bins from outside for control moisture.
5. Place storage bins in the house on high-raised platform at least 30 cm off the ground and 30-40 cms away from the sides/walls of the house to allow enough ventilation and light to reduce the chances of rodent attack and increase aeration to get rid of dampness.
6. Install tightly closing, lockable outlets on the mud-bins for controlling rats.
7. Regularly re-plaster, repair, and seal the cracks and crevices as of these structures and use sanitary/preventive measures and maintenance.
8. Earthen/clay pots are bitumen/tar painted and lids are also painted and smeared/sealed with the dough of wheat and/or maize flours/cow-dung-mud mix to make it airtight and moisture proof.

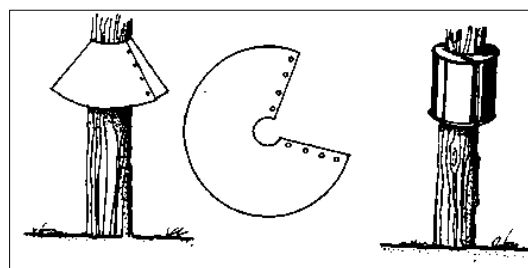


Figure 12. Locally produced rat guards

## F. VEGETABLES

In total, there are about 150 Market Planning Committees (MPC) within the KISAN project districts. Of these, about 45% are functional, 20% are semi-functional, and 30% are non-functional. We visited two collection centers, two wholesale markets, and one farmer group. KISAN works on improving vegetable production and marketing, but this is constrained by the high amount of estimated vegetable losses that different stakeholders cited for the various types of vegetables. These losses were evaluated through interviews with different stakeholders. Table VI below summarizes the losses for each vegetable estimated by each stakeholder group.

**Table VI. Vegetable loss estimates at various stages**

<b>Crops</b>	<b>Chinchu Farmers Group</b>	<b>Kunathari Collection Center</b>	<b>Babu and Shahi Surkhet Wholesaler</b>	<b>Wholesaler Kohalpur Market</b>
<b>Potato</b>	2-5%	2-5%	5-7%	5-10%
<b>Onion</b>	-	-	4-5%	2-3% (but product was sprouting)
<b>Cauliflower</b>	3-5%	4-5%	5-7%	1 day 10%
<b>Cabbage</b>	2-3%	2-3%	2-4%	4-5%, but in rainy season up to 15%
<b>Chili</b>	0.5-1%	0.5-1%	1-2%	1-2% within 7 days
<b>Tomato</b>	2-5%	3-5%	4-5%	5-7% on average, in rainy 15%, during winter lower 1-2%
<b>Carrot</b>	-	3-5%	5-8%	low during winter, summer 25% (color deterioration)
<b>Brinjal/ Aubergine</b>	5-8%	5-7%	7-10%	10-30%
<b>Cucumber</b>	-	-	-	8-10%
<b>Tomato</b>	3-5%	3-4%	5-7%	5-7% on average, in rainy 15%, during winter lower 1-2%
<b>Radish</b>	1-2%	1-2%	2-3%	2-3%
<b>Beans</b>	2-4%	2-4%	4-6%	5-7%
<b>Capsicum</b>	1-2%	1-3%	2-4%	3-5%
<b>Bittergourd</b>	3-5%	4-5%	5-7%	8-10%
<b>Bottle</b>	1-3%	2-4%	3-5%	5-7%

**Table VI. Vegetable loss estimates at various stages**

Crops	Chinchu Farmers Group	Kunathari Collection Center	Babu and Shahi Surkhet Wholesaler	Wholesaler Kohalpur Market
<b>gourd /Pumpkin</b>				
<b>Ginger</b>	1-2%	1-3%	2-5%	2-5%

These losses add up so by the time products reach consumers total losses from farmer to market are significant. Steps need to be taken along the value chain to reduce post-harvest losses.

## F.1 Cauliflower & cabbage

### F.1.1 Description of observed post-harvest system

**Harvest:** Cabbage and cauliflower are managed in similar ways. Farmers harvest them with a sickle or large knife as they could be damaged if harvested just by hand. Farmers remove lower side leaves for cauliflower and the damaged cabbage leaves. They then bend the higher leaves around the cauliflower to protect it. Damaged, diseased, and insect infested heads are set aside.

**Transporting:** These vegetables are transported in a *doko*, or sometimes in a bag (polypropylene, jute). Sometimes the vegetables are damaged in *doko* due to rough handling. When traveling to the wholesale markets, the vegetables inside the *doko* or bag are loaded onto buses, trucks, or small vehicles with no packaging. This practice degrades the quality of the product.

**Storage at collection centers and wholesale markets:** At the collection center, cabbage and cauliflower can be stored for up to three days. There is no grading, and often the cabbage and cauliflower are piled on the floor with no protection. Similarly at the wholesale market, they can be left on the ground for a couple of days. Sometimes to reach the next market they are packed in bags. At the end market, (often five to seven days from the farm), the vendor spreads the vegetable out on a tarpaulin, jute bag, or open cart. At each stage, the quality of the produce suffers. A detailed description of the supply chain of cabbage in Laos can be found<sup>46</sup> – this could be an example for a more detailed study.

### F.1.2 Current practices, associated losses, and recommended practices

**Table VII. Current practices, associated losses, and recommended practices for cabbage and cauliflower**

Value chain step	Current practice	Losses	Recommended/improved practice
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<sup>46</sup> [http://www.ifrj.upm.edu.my/19%20\(04\)%202012/44%20IFRJ%2019%20\(04\)%202012%20Antonio%20Phillipines%20\(339\).pdf](http://www.ifrj.upm.edu.my/19%20(04)%202012/44%20IFRJ%2019%20(04)%202012%20Antonio%20Phillipines%20(339).pdf)

<b>Production</b>	Late application of fungicide, insecticide (close to harvest date) Late and too much fertilizer		Waiting period after insecticide application respected – 15 days No late fertilization
<b>Harvest</b>	Harvest in morning or during day Harvest with sickle Put in a pile in the sun in the field	2-5%	Respect maturity <sup>47</sup> ; harvest in evening or late afternoon; cut with sickle making sure not to damage the head; vertical cut; use pre-cooling – in shade, under roof or tree Depending on market – sort by size.
<b>Transport to collection center</b>	In dhoko, with straw, leaves, or paper on foot usually overloaded containers		Transport evening or late afternoon if they are going to be transported for long distances. Early in the morning if going to local markets. Use crates or sturdy packaging, and sorted according to size. Crates and goods should not exceed 15 kg
<b>Holding at collection center</b>	In pile on the floor sometimes on tarpaulin or plastic or jute sacks, all sizes of cabbage or cauliflower are together	4-5%	Sorting and grading, store in crates in the shade. Keep products damp
<b>Transport to wholesaler/ market</b>	Mini truck, truck, bus in baskets and crate, sacks, piled in transport vehicle without container Goods piled on top of each other, open		In covered crates, no overloading, covered with tarpaulin. Transport evening or at night – keep as cool as possible. Keep damp
<b>Wholesaler/ market</b>	In pile on the cemented floor	5-7%	In sorted crates, if stored at around 0°C can be stored for 6 months
<b>Retailer/ market</b>	In pile on cemented floor & soil	1 -15%	In sorted crates; if stored at around 0°C can store for 6 months

## F.2 Tomato

### F.2.1 Description of observed post-harvest system

**Harvest:** This is the most important vegetable crop for offseason farmers. Thick skin tomato varieties are preferred since they withstand transport better. Also, some varieties like the local sour tomatoes are preferred since they have specific food uses and are used for chutney and sauces. Tomatoes are harvested



Figure 13: Sorting of tomato

<sup>47</sup> <http://postharvest.ucdavis.edu/pfvegetable/Cabbage/>

by hand and are climatic fruits meaning they still ripen once harvested. Tomatoes can be harvested at many color stages depending on the distance to the market. UC Davis has a useful color chart<sup>48</sup>. Tomatoes are harvested over a longer period – for some determinate varieties farmers harvest the same field one to four times. For indeterminate varieties harvesting goes on for several months. Following harvest, tomatoes are put into baskets or in piles in the field. Sorting is often dependent on where the tomatoes are to be sold. For local sales, farmers harvest ripe or almost ripe tomatoes. But in general, farmers visited did not practice sorting or grading of tomatoes in the field to select for maturity and size. Damaged and pest-infested tomatoes are sorted out to be left in the field or taken home for home consumption.

**Transport:** By bus, car, or truck, collectors transport vegetables overnight to benefit from the cool temperatures. Producers or collectors will transport tomatoes in a loose heap in the back of the truck or in cartons, baskets, crates, or *dokos*. The latter can be lined with vegetable material to protect tomatoes from shocks and pressure. Individual baskets rest on top of each other effectively compressing the goods below. Sometimes tomatoes are transported in plastic carrier bags, which have a lower overall weight than *doko*, but have no protection from post-harvest damage. Most MPCs, wholesalers, and others are familiar with standard plastic transport crates.



Figure 14: Tomatoes in crates ready for transport

**Storage at collection centers and wholesale markets:** Tomatoes can be stored in winter at ambient conditions for 10-15 days if harvested green, while in the summer the storage period is three five days maximum. Wholesalers often allow customers choose their products, which leads to more and more fruits being damaged as the pile reduces. Retailers often sort out already damaged tomatoes and sometimes sell those fruits for a lower price or take them home for self-consumption.

## F.2.2 Current practices, associated losses, and recommended practices

**Table VIII. Current practices, associated losses, and recommended practices for tomatoes**

Value chain step	Current practice	Losses	Recommended/improved practice
<b>Production</b>	Late application of fungicide, insecticide (close to harvest date)  Late and at times excessive fertilizer and water use  Sorting out of damaged, diseased, and	17-22%	Waiting period after pesticide application respected – 15 days  No late fertilizer  Late watering will increase spoilage depending on harvest

<sup>48</sup> <http://postharvest.ucdavis.edu/pfvegetable/TomatoPhotos/?repository=30014&a=83755>

	small tomatoes		season (monsoon or winter) and where tomatoes plan to be sold, need to reduce watering as tomatoes reach full size to speed up ripening and avoid spoilage
<b>Harvest</b>	Harvest in morning or during day Harvest by hand turning of tomato Put in a pile in the sun in the field	2-5%	Respect maturity index <sup>49</sup> ; harvest in evening; cut with scissors, secateurs, or sharp knife and leave a bit of the stem on the tomato; cut stems vertically to avoid damage; use pre-cooling <sup>50</sup> – in shade, under roof.  Plan the harvest- know where the tomatoes are going and how long they will be transported. Then
<b>Transport to collection center</b>	In doko, with straw, leaves or paper carried on foot; transport charges are calculated on the number of containers, not by weight, leading to large, overloaded containers	1-2%	Send early in the morning; transport in crates, already sorted; crates and goods should not exceed 15 kg
<b>Holding at collection center</b>	In pile on the floor sometimes on tarpaulin or plastic or jute sacks, all sizes of tomatoes together,	3-5%	Sort and grade tomatoes, store in crates.
<b>Transport to wholesaler/ market</b>	Mini truck, truck, bus in baskets and crate, sacks, piled in transport vehicle without container  Goods piled on top of each other, open under sun	3-4%	In crates, no overloading, covered with tarpaulin; use plant material to cushion the crop in transport
<b>Wholesaler /market</b>	In pile on the cemented floor	6-9%	In sorted crates. Keep moist and as cool as possible.
<b>Retailer/ market</b>	In pile on cemented floor & ground; handling by customers increases losses	3-5%	In sorted crates. Keep cool.

### F.3 Curcubits (pumpkin, bitter gourd, bottle gourd, cucumber)

#### F.3.1 Description of observed post-harvest system

**Harvest:** Fruits are harvested at full maturity when they attain their maximum sizes. Farmers harvest bitter gourd generally at 15-20 days after fruit set or 90-95 days after planting when fruit becomes light

<sup>49</sup> <http://postharvest.ucdavis.edu/pfvegetable/TomatoPhotos/?repository=30014&a=83755>

<sup>50</sup> <ftp://ftp.fao.org/docrep/fao/012/i0782e/i0782e01.pdf>

green, thick, and juicy and the seeds are soft and white. Depending on the bitter gourd variety, five to seven harvests are made from each plant. Harvesting is done by hand picking; in some places knife is also used. Harvesting is done in the late evening hours.

Harvested produce is collected under shade and fruits are sorted based on disease infections, insect damage, and plant nutrient deficiency. The poor quality fruit are thrown away or given to animals. After harvest, gourds and cucumbers are kept under the shade to facilitate cooling. Farmers sprinkle water to remove field heat and to maintain freshness. If required, storage is done inside the room at room temperature.

**Transporting:** Prior to transport, the harvested curcubits are packaged in plastic and/or gunny bags and then sent to the market. Rough holes are created in the plastic for aeration.

For local markets, the produce is brought either by rickshaw, tempo, truck, tractor, bus, and minibus. Sometimes the vegetables are damaged. When traveling to the wholesale markets, the vegetables are loaded onto buses, trucks, or small vehicles within double bagged plastic bags. This practice can degrade the quality of the product.



Figure 15: Curcubits in plastic bags for transport.

**Storage at collection centers and wholesale markets:** Retailers will remove damaged gourds and cucumbers, and throw them away. To keep fruits fresh during marketing, they are covered with gunny bags and water is sprayed over the gunny bags to keep the fruits fresh. The long market chain – farmers to commission agent to wholesaler to retailer to consumer – impacts the quality of the product.

### F.3.2 Current practices, associated losses, and recommended practices

**Table IX. Current practices, associated losses, and recommended practices for cucurbits**

Value chain step	Current practice	Losses	Recommended/improved practice
<b>Production</b>	Some farmers practice late application of pesticides, and use highly toxic insecticide such as Endosulphan and Malathion		Respect waiting period Need to sort out damaged and diseased fruits; harvest at maturity
<b>Harvest</b>	Harvesting is done by hand picking, in some places knife is also used	3-5%	While harvesting, 2-3 inches of stem needs to be left attached to the fruit; complete removal of stem from the fruit shortens the storage life
<b>Transport to collection</b>	In doko or cloth		Transport in crates to avoid damage of the fruits Temporarily stored in shade before packing

<b>center</b>			and transporting
<b>Holding at collection center</b>	In gunny or in plastic bags, at ambient temperature; sometimes out in the open air under the sun	4-5%	Keep in a cool well aerated place, well away from the sun  Bitter gourds have a relatively high respiration rate, use evaporative cooling (spray with water) in regions with hotter climate to improve crop storage
<b>Transport to wholesaler/ market</b>	In gunny or in plastic bags; in wooden or plastic crates  Goods are often piled on top of each other		Before packing, neem leaves or newspaper is spread at the bottom as padding material; fruits are carefully piled up and covered with gunny bags before sending to the market
<b>Wholesaler /market</b>	In plastic bags or crates, or in piles on the ground  Fruits stored at 15°C and above continue to develop, leading to loss of green color, seed development, and fruit splitting	5-7%	KISAN can promote coolbots or possibly charcoal cool stores evaporative cooling to maintain a cool interior temperature for refrigeration and food preservation. The cool stores are built with open timber frames lined with charcoal-filled sides. The charcoal is kept moist, and as warm, dry air passes through, the water on the charcoal evaporates and cools the air. Farmers/wholesalers can store produce in the cool store for up to three days before taking it to the market, minimizing postharvest losses.
<b>Retailer/ market</b>	In baskets; retailers cover the fruits with gunny bags and keep on spraying water over the gunny bags to keep the fruits fresh	8-10%	If washing has to be employed, the wash water must be clean or sanitized with chlorine; after washing, the fruit must be dried properly to prevent decay

## F.4 Chili

### F.4.1 Description of observed post-harvest system

**Harvest:** Depending on the variety and market demand for green or red fruit, harvesting chili begins 50 days after transplanting for green, immature chili. If the market prefers the chili fruit ripe, harvesting will begin 70 to 80 days after transplanting. Harvest time depends on how well the farmer manages the crop and can last up to 100 days, but is usually between 50 to 60 days. Chilis are harvested by hand; they are non-climatic fruits and will not ripen further once harvested. Good quality fruit should be uniform in shape, size, and color typical of the variety.

Green fruit are harvested every two to three days. Ripe fruit should be harvested weekly, preferably during the early part of the day. The fruit is harvested by removing it from the branch, ensuring the stem remains intact and attached to the fruit. During harvest, overripe soft fruits are also removed from the plant and thrown away.

Chili are cleaned in the field and sorted by hand. Fruits with defects such as cracks, decay, physical damage, and sunburn are sorted out. Undersized, shriveled, dull-looking, pitted, or softening fruit are also discarded. The chilis are cleaned to remove debris and soil particles.

**Transportation:** Bamboo baskets or wooden crates are used to transport chili to the market; sometimes plastic or mesh bags are used. Plastic crates offer better protection against physical injuries than the other containers due to their smooth surface, rigidity, and ease in handling.

Chili is susceptible to physical damage, particularly if it is transported in sacks or bags. Any cracks, splits, or punctures will cause the fruit to deteriorate rapidly. Discoloration, decay, and tissue breakdown are the common symptoms of damage. Often goods are transported overnight to profit from the cool night air, and protect goods from exposure to direct sunlight.

**Storage at collection centers and wholesale markets:** Chili are stored on the ground in a pile, in plastic bags, or in sacks made of netting. They should be stored in a dry and cool, with good ventilation. They are usually sold within three to five days.

#### *F.4.2 Current practices, associated losses, and recommended practices*

**Table IX. Current practices, associated losses, and recommended practices for chilis**

Value chain step	Current practice	Losses	Recommended/improved practice
<b>Production</b>	Late application of fungicide, insecticide (close to harvest date) Late and too much fertilizer	3-7%	Respect waiting period prior to harvest  Do not need fertilizer application if manure application is sufficient and regular
<b>Harvest</b>	Chili are harvested by hand, they are non-climatic fruits and will not ripen further once harvested	0.5-1%	Harvested fruits can be placed directly into plastic field crates or into smaller plastic buckets, which are then transferred to crates at the side of the field. The harvested fruit should be kept in shaded conditions and be protected from the sun and wind.
<b>Transport to collection center</b>	Chili are transported in packaging that is not sturdy enough Packages are loaded on top of each other	0.5-1%	When chili is transported in bamboo baskets or wooden crates liners, such as fresh leaves, old newspaper, and proper strapping or binding of the container is recommended  Baskets of produce should not be stacked on top of one another unless a rigid divider is provided in-between layers in a stack  Plastic or mesh bags and sacks are not

			recommended unless they are placed in a rigid container
<b>Holding at collection center</b>	In the transport bags	0.5-1%	Keep in a cool shaded place
<b>Transport to wholesaler/ market</b>	In gunny bags or plastic bags	1-2%	Use crates to transport produce, but do not stack crates, stacking crates puts too much pressure on bottom crates, damaging produce  Avoid overloading each transport container which can cause bruising or damage by compression  The fully loaded container should be taken to a shaded, well-ventilated temporary holding area
<b>Wholesaler /market</b>	Piled on the floor; when stored above 13°C, chili is subject to accelerated ripening and bacterial soft rot infection	1-2%	Sorting out of damaged fruits
<b>Retailer/ market</b>	In baskets on cloth on the ground	1-2% within 7 days	Keeping chili cool and market rapidly

## F.5 Long Bean

### F.5.1 Description of observed post-harvest system

**Harvesting:** The yard long bean is typically harvested when the pods have reached a minimum length of 38 to 45cm. The most popular cultivars have a medium green color. The highest quality pods are straight, crisp, and uniform in color. Harvesting can be done by pinching the stem with the thumbnail pressed against the index finger. Pods should be well-formed and straight, uniform in color with a fresh appearance, and tender but firm. They should snap easily when bent. Pods are sorted to remove any leaves, stems, broken pods, blossom remains, and insect-damaged or partially decayed pods.



Figure 16: Farmer harvesting long beans

**Transporting:** The vehicle used for transporting should have a roof to shade the loaded crates. Avoid stacking baskets on top of each other, use crates if possible. The vehicle should have a shelf for basket

loading. Transport to the market should be done early in the morning, afternoon, or at night to avoid dehydration.

Put beans in a plastic basket, crate, or bamboo basket (use liners such as banana leaves or cushions to cover the rough angles). Arrange them in a semi-circle in a bamboo basket and pile horizontally. Avoid over-stacking, which can cause bruising or damage by compression. Yard long beans are typically wrapped in bunches for marketing.

**Storage at collection centers and wholesale markets:** Long beans are susceptible to water loss during storage. Therefore, use a wet cloth or jute sack to cover the baskets, which is frequently sprinkled with clean water. Long beans are kept for maximal seven days.

#### *F.5.2 Current practices, associated losses, and recommended practices*

**Table X. Current practices, associated losses, and recommended practices for long beans**

Value chain step	Current practice	Losses	Recommended/improved practice
<b>Production</b>	Spoiled products are sorted out	8%	Yard long bean can be harvested 35 to 40 days after transplanting, depending on cultivars
<b>Harvest</b>	Harvesting is done during the coolest time of the day, which typically is in the early morning  Immediately after harvest, most farmers store the produce on the ground in the shade	2-4%	Avoid harvesting in the afternoon, as the pods will lose too much water during the day (dehydration) and will not be crisp enough  Use pruning shears or scissors to harvest, always leave at least one centimeter of stem and avoid tearing the pods  After harvesting, avoid direct exposure to the sunlight – heat increases the pod respiration rate and in a few hours (less than 5 during the dry period) it can lose up to 10% of its weight  Spread the pods out in a shallow layer on top of a clean, flat surface, which helps to dissipate field heat before packing
<b>Transport to collection center</b>	Beans are usually packaged in sacks, plastic bags or bamboo baskets; paper is used to cushion the baskets	1%	Sort the beans into three categories according to length, maturity, and external appearance  Never pack the pods too tight. They should be loosely packed within the

			crate to allow for adequate heat dissipation
<b>Holding at collection center</b>	In plastic bags; wrap in bundles with paper	2-4%	Gunny or polypropylene bags should not be used because the pods will rapidly heat and wilt due to restricted ventilation; clean and grade for value addition
<b>Transport to wholesaler/ market</b>	Packed in plastic bags and bamboo baskets, beans damage easily during transport	1%	Use paper, carton, cloth to cushion the beans inside the baskets
<b>Wholesaler/ market</b>	Try to sell all the produce in one day, beans don't keep well	4-6%	Use water or wet sack to cover beans to keep them fresh
<b>Retailer/ market</b>	Keep in shade, do not expose to direct sunlight	5-7%	Use water or wet sack to cover beans to keep them fresh

## F.6 Okra

### F.6.1 Description of observed post-harvest system

**Harvesting:** Under normal growing conditions, the first pods are ready for harvest within two months after seeding. The plants continue to flower and set fruit over at least three months under favorable weather conditions, if the pods are regularly harvested. Okra pods are ready for harvest four to six days after flowering. Okra pods are ready for harvest when they are about 2-4 inches or 4-9 cm long or while the pod is soft and tip snaps. The pods are bright green fleshy and seeds are small. The pods should be gathered every day.

Mechanically or physically injured fruits during transit were found to be prone to infection and such fruits should be stored separately to avoid fruit to fruit (post-harvest) spreading of pathogens. Removing the diseased fruits from the others was found to be the best practice of the traditional storage methods. In laboratory experiments, the best method to improve shelf life is to store fruits between 80%-95% relative humidity and 5-10°C temperature in properly ventilated containers. The fruit lasted for 15-20 days. The storage container should be properly ventilated for longer storage periods due to high respiration rate of okra fruits shows fast spoilage.

**Cleaning and sorting:** Field sorting or removal of rejects is done in the field. The pods are selected and sorted based on size (4-9 cm long is ideal), color (bright green is best), number of ridges (five), visual quality (clean and free from bruises), and based on insects damage and diseases. Grading is done by hand. The initial grading of the harvested okra takes place in the field at the time of harvest. Pickers separate unmarketable or damaged pods from the marketable ones.

**Storage at collection centers and wholesale markets:** Okra should not be stored with tomatoes and muskmelons. These crops produce ethylene and okra is ethylene sensitive. Fresh okra bruises easily; the bruises blacken within a few hours.

## F.6.2 Current practices, associated losses, and recommended practices

**Table XI. Current practices, associated losses, and recommended practices for okra**

Value chain step	Current practice	Losses	Recommended/ improved practice
<b>Harvest</b>	They are usually handpicked and sharp knives are used to cut them from the stalks to avoid fruit damage such as bruises and discoloration	5-8%	Okra pods are ready for harvest when they are about 2-4 inches or 4-9 cm long or while the pod is soft and tip snaps. The pods are bright green, fleshy pod and seeds are small. Avoid early picking, the pods should be gathered daily
<b>Transport to collection center (same or next day)</b>	Okra is packaged in sacks or baskets, although these packages provide minimal protection to the contents		Okra should be cooled within a few hours after harvest to prevent pod darkening and deterioration
<b>Holding at collection center (maximal 2 days)</b>	In bags or sacks deposited on the floor	5-7%	Temperature above 10°C cause yellowing, toughening and rapid decay
<b>Transport to wholesaler/ market</b>	In trucks and buses		Transport in boxes, well packaged
<b>Wholesaler/ market</b>	Decay is mostly associated with damaged or wounded areas of the pod	7-10%	Okra in good condition can be stored seven to ten days
<b>Retailer/ market</b>	In baskets or sacks	10 - 30%	Avoid water on the fruits, might lead to browning and rot

## F.7 Onion

### F.7.1 Description of observed post-harvest system

**Harvesting:** Bulb onions reach maturity four months after transplanting to the field and are ready to harvest after five to six months. During bulb ripening, farmers should not water the crop. As onions mature, tops begin to fall and dry – maximum yield is attained when tops are completely down and dry. Bend green part downward to enhance curing process before lifting from field.

**Cleaning and sorting:** Sorting and grading should be done at field level to minimize post-harvest losses at subsequent stages. Sort out onions that are damaged and show rot. After harvesting, the curing process is important. Cut the leaf from the bulb, leaving less than half a centimeter of the neck. Dry the bulb in the sun as often as possible to ensure the neck heals completely. Both curing and drying remove excess moisture from the outer layers of the bulb prior to storage. Drying also reduces shrinkage during subsequent handling, reduces the occurrence of sprouting, and allows the onion to ripen before fresh consumption or long-term storage. Avoid damage during grading and packaging.

**Storage at collection centers and wholesale markets:** The humidity should be about 75% and the temperature 25°-30°C. If the temperature drops much below 18°C the onions may begin to sprout. In Nepal, the onions are bulk stored in special houses with thatched roof and side walls are made up with bamboo sticks or wire mesh for good air circulation. Sometimes the sides are also covered with gunny cloth.

#### *F.7.2 Current practices, associated losses, and recommended practices*

**Table XII. Current practices, associated losses, and recommended practices for onion**

<b>Value chain step</b>	<b>Current practice</b>	<b>Losses</b>	<b>Recommended/ improved practice</b>
<b>Production</b>	Plants are watered up till the harvest date		No late watering and fertilization, otherwise storage shelf life is impacted  Stop watering onions 2 weeks before the harvest date  Excessively field-drying onions increase the risk of loss
<b>Harvest</b>	As onions mature, tops begin to fall and dry  Shade curing for 10 days  Green tops of onions are cut off with a knife to facilitate drying		Maximum yield is attained when tops are completely down and dry  For maximum storage life, optimum harvest would be when onion foliage is still partially (30% to 40%) erect, since yields may increase 30% to 40% between the stage when tops begin to go down, and the leaves are fully down and dry – there is need to take this into account  Shade curing after field curing and neck cut to remove excess moisture from surface of bulbs and to remove the field heat before packing, transportation, or storage is essential operation
<b>Transport to collection center (same or next day)</b>	Onions are transported in polypropylene bags or jute bags		Perforated hessian bags and plastic-woven bags are used for onion packing to permit proper ventilation. Tier system of transportation on poor roads, restriction of loading height in trucks and wagons, providing ventilation in railway wagons and quick movement of onion wagons or truck loads are other factors which can help in minimizing the post-harvest losses of

			onions
<b>Holding at collection center (maximal 2 days)</b>	In polypropylene bags or jute bags, or in piles on the ground		Avoid bruising by careful handling, onions should not be dropped from big height during handling to avoid bruising
<b>Transport to wholesaler/ market</b>	In polypropylene bags or jute bags Onions are transported in bullock carts, tractor, buses, and trucks		Pack onions in mesh bags to facilitate aeration
<b>Wholesaler/ market</b>	In a pile on the ground, or in baskets	4-5%	Onions should be transported and stored separately from other kinds of produce. Many types of fruits and vegetables will readily absorb the odor of onions. Well -dried onions also draw moisture readily from fresh vegetables  Onions are stored in sheds by spreading them on dry and damp proof floor or racks. Periodical turning of bulbs or removal of rotten, damaged and sprouted bulbs should be done. Well-ventilated improved storage structures with racks or tiers having two or three layers of bulbs would be desirable for proper storage
<b>Retailer/ market</b>	In a pile on the ground in baskets	2-3%	Ensure that onions are sufficiently aerated, throw away infected and rotting onions

## F.8 Aubergine/Eggplant

### F.8.1 Description of observed post-harvest system

**Harvesting:** Traditional teardrop shape fruit varieties are ready for harvest 50-70 days after transplanting or one month after fruit set. Depending on variety, plants can crop for up to five months. Fruit is harvested when it reaches a glossy deep purple color, but before seeds begin to harden and turn brown. Test for maturity by pressing with the thumb. If the flesh springs back, the fruit is green; if it does not and an indentation remains, the fruit is mature. Harvest when the fruit is about halfway between these stages. Mature fruit should not be left on the plant because they will reduce overall productivity.

Use a knife or pruning shears to cut the fruit from the plants. The calyx or cap should be fresh and green in appearance and left attached to the fruit. The length of the stem should be cut short (2.5 cm or 1 in) to avoid puncturing of adjacent fruit. Cotton gloves should be worn during harvest to protect the picker's hands against injury from spines on the calyx and to minimize fruit damage. Deformed, sunburned, insect-damaged, and diseased fruit should be removed from the plant and discarded. Harvest

frequency is typically once per week. Over-mature fruit have a dull color, crinkled skin, spongy feel, and wrinkled stem.

Harvested eggplants should be carefully placed in a suitable container for transport from the field. Careful handling is necessary because even slight bruising will disfigure the skin. Harvested fruits, especially the purple-skinned types, should be protected from the direct rays of the sun because they are highly susceptible to sunburn. Under conditions of high solar radiation, an exposure period of one hour is sufficient to cause fruit softening and skin shriveling, which may render fruits unmarketable. The fruits should be kept in well-ventilated shaded areas to minimize the buildup of heat and maintain acceptable fruit quality.

**Transportation:** Rapid cooling, primarily to reduce water loss, soon after harvest is essential for optimal post-harvest keeping quality. Sort out damaged, insect infested, and non-standard fruits prior to transport. Eggplants are transported in bags, rarely crates. Fruits are cleaned with a cloth prior to shipping. The fruit are susceptible to bruising and compression injuries during transit and distribution so caution is required to avoid bulking or over-packing.

Strong ventilated plastic containers are ideal. If wooden crates or baskets are used as field containers, they should be lined with newspaper or protective padding. Sacks or bags should not be used since they typically cause abrasion and physical damage to the fruit.

The fruit can be cleaned by washing in chlorinated water (150 ppm free chlorine with pH 6.5) or wiping with a damp cloth. This also helps to add shine to the surface and improve the external appearance. Consumers are typically attracted to a smooth, shiny eggplant.

The fruit should be laid flat and arranged horizontally along the same plane inside the carton. This will prevent the stem from puncturing adjacent fruit.

**Storage at collection centers and wholesale markets:** Storage periods in excess of 14 days (shorter under hot conditions) result in changes to the visual and sensory qualities, after which decay occurs. Under conditions of Nepal, traders try to sell all their eggplants in less than a week.

Fruit are sensitive to relative humidity – humidity levels below the optimum of 90-95% will result in a loss of visual quality, drying of the calyx, and weight loss. Storage with high-odor products, such as ginger, melon or onion, should be avoided as there is a risk of scent being absorbed by the fruit, resulting in an off-flavor.

Aubergine is very susceptible to water loss and shriveling. Symptoms may become evident with as little as 3% water loss. Visible signs of water loss are reduction of surface sheen, skin wrinkling, spongy flesh, and browning of the calyx.

#### *F.8.2 Current practices, associated losses, and recommended practices*

**Table XIII. Current practices and recommended practices for aubergine/eggplant**

Value chain step	Current practice	Losses	Recommended/ improved practice
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<b>Production</b>	Frequent pickings will result in higher yields		Harvest 50–70 days after transplanting or one month after fruit set, depending on variety, plants can crop for up to five months
<b>Harvest</b>	Optimum maturity is judged by size, and the fruits should be relatively heavy in relation to their size  Fruits become bitter when they are collected over-mature.		Cut fruits with knife or secateurs, leaving a short piece of stem attached to the fruit; put in shade after harvest to cool  Eggplant should be harvested during the coolest time of the day, preferably early in the morning and avoid prolonged exposure to the sun – harvested fruit should be kept as cool as possible
<b>Transport to collection center (same or next day)</b>	Fruits are generally sorted by size and color		Sort out damages, insect infested and non-standard fruits prior to transport
<b>Holding at collection center (maximal 2 days)</b>	In piles on the floor, in bags		Fruits are cleaned with a cloth prior to shipping; fruits are susceptible to bruising and compression and caution is required to avoid bulking or over-packing
<b>Transport to wholesaler/ market</b>	Eggplant are transported in bags, rarely crates		Harvested fruit should be carefully placed inside smooth-walled containers with the stem oriented away from the skin of an adjacent fruit
<b>Wholesaler/ market</b>	Nepali traders try to sell all their eggplants in less than a week.		Storage periods in excess of 14 days, under hot conditions even shorter, result in changes to the visual and sensory qualities, after which decay is will occur
<b>Retailer/ market</b>	Nepali traders try to sell all their eggplants in less than a week		Eggplants are best kept in cold storage at temperatures between 7-10°C

## F.9 Recommendations on needed research and training for vegetables

- I. Marketing chain is too long and impacts quality of the product and revenue of producers.

**Recommendations:** Shorten the marketing chain between the field and the consumer by:

- a. Taking out certain actors in the market chain and selling directly to consumer or large supermarkets; and

- b. Organizing better transport systems by using either refrigerated trucks or covered trucks.

### **Production:**

2. Late fertilization and watering impacts the fruit quality and storage life of fruits. These practices lead to heavier and more water-filled fruits that are more susceptible to damage.

**Recommendations:** Develop a plan for correct fertilization and water-management for each crop.

3. Late application of pesticides can lead to health risk for consumers.

**Recommendations:** Farmers should be made aware of the 'waiting period' for each class of pesticides. KISAN should also emphasize correct reading of label of pesticides. Train farmers and Agrovets on pesticide use and correct waiting period. Post-harvest quality can be impacted by late and wrong application of pesticides – e.g. burning of fruits, shriveling, and visible residues of pesticide application.

### **Harvesting:**

4. Crops are harvested without taking into consideration their maturity index.

**Recommendations:** Determine the right timing for harvesting based on maturity and the market requirements, including matching crop maturities to intended markets and distance of these markets.

**Table XIV. Maturity index and maturity signs for different vegetables**

<b>Vegetable</b>	<b>Days to Maturity</b>	<b>Size</b>	<b>Color</b>	<b>Comment</b>
<b>Cabbage</b>	60-90 after planting	Varies with cultivar	Green, red	Harvest when heads are large and solid
<b>Cauliflower</b>	55-80 after planting	18 to 23 cm across	Creamy white	Blanch heads when 2-3 across by carefully tying leaves over heads
<b>Cucumber</b>	55-65 after planting	15-18 cm long	Dark green	Harvest plants every 2 to 3 days, leave small piece of stem attached to fruit
<b>Pumpkin</b>	85-120 after planting	Varies with cultivar	Orange	Harvest when uniformly orange, leave 3-4 cm of stem
<b>Eggplant</b>	75-90 after planting	Varies with cultivar	Purple, white, green	Fruit should have shiny finish
<b>Bittergourd</b>	8 to 10 days after flowers open	10 to 15 cm long.	Light green	Young fruits should be harvested, while the fruits are still firm

**Table XIV. Maturity index and maturity signs for different vegetables**

Vegetable	Days to Maturity	Size	Color	Comment
<b>Bottlegourd</b>	60-120 days after sowing	Varies with cultivar	Light green	Cut the fruits, leaving 3-4 cm of the vine
<b>Okra</b>	50-65 after sowing	3 to 10 cm long	Bright green	Harvest frequently to maintain productivity
<b>Onion</b>	100-120 after planting	Varies with cultivar	White, yellow, red	Harvest when tops fall over and begin to dry
<b>Chili</b>	60-90 after sowing	3 to 10 cm long	Red, purple, yellow, green	Use gloves when harvesting
<b>Tomato</b>	70-90 after planting	Varies with cultivar	Red, orange, yellow	Harvest fully ripe for best flavor; leave stem attached
<b>Long Beans</b>	60 days after sowing	35-75 cm	Light green	It is important not to pick the buds which are above the beans; since plants will set beans on the same stem

5. Fruits are harvested using inappropriate tools and methods, leading to damage and deterioration of quality.

**Recommendations:** Use the right tools for harvesting, either knives and/or encourage the use of scissors or secateurs for reducing damage to the fruit. Teach farmers the right form of cut and how to leave pieces of the stem to avoid post-harvest damage.

6. Harvested fruits are handled roughly; inappropriate handling after harvest.

**Recommendations:** Harvested fruits can be placed directly into plastic field crates or into smaller plastic buckets, which are then transferred to crates at the side of the field. The harvested fruit should be kept in shaded conditions and be protected from the sun, wind, and rain. Harvesting during or just after rain is not recommended because wet conditions favor disease development and enhance fruit breakdown.

7. Harvested fruits are left in the sun, no cooling of goods after harvest.

**Recommendations:** After harvesting, fruits should be cooled down by placing them in the shade or under a tree to dissipate heat before they are packed.

### **Sorting:**

8. There is very little sorting and grading of harvested vegetables in the field.

**Recommendations:** Sorting, grading, and packaging should start from the farmers' fields, but there is need for economic incentives if this practice should be maintained. Vegetables that are

damaged, show blemishes, are pest infested or otherwise of lower grade need to be separated out. These can be used for home consumption or given to animals. In the worst case, they should be used to make compost. Diseased crops should not be left in the field since they might be sources for contamination.

9. Stakeholders need to be trained on sorting methods and specifications.

**Recommendations:** Training on sorting of vegetables according to standard end-user requirements in Nepal.

Vegetables may be classified by color, size, or variety and should be placed together in the same container. Additionally, they should be:

- Free from soil and debris;
- No overripe or softening fruit;
- Free of microbial infections or insect infestations;
- Fruits have no mechanical damage, splitting, or cracking; and
- Stems are intact and green.

10. Vegetables arrive in the markets in dirty and unhygienic condition.

**Recommendations:** Wash or clean vegetables. Potential washing methods include:

- Washing in 300 ppm (30g/L) chlorine solution or sodium hypochlorite; this can also reduce disease and should be followed by proper drying.
- Another safe and simple treatment is to dip the chili fruit in hot water. Dipping chili in 53 to 55°C water for four minutes can effectively control botrytis rot without causing fruit injury.

### **Packaging:**

11. Presently, mostly poor quality containers including cloth bundles, jute or polypropylene sacks, woven plastic bags, divers models of woven baskets, Styrofoam crates, paper cartons, and wooden crates are being used in Nepal.

**Recommendations:** Innovative packaging.

- ✓ Plastic crates

Allow fruits to withstand rough roads when transported from farm to packaging sites. These crates are reusable for a number of trips.

- ✓ Collapsible metal crates



Figure 17: Chillis in jute sacks in market

Reduce damage during transport and eliminates 10%-15% losses of conventional packaging. Save on space when transported back empty after delivery. However, to recover the cost, the metal crates have to be used at least 80 times.

✓ Display ready boxes

Reduces handling losses in terms of bruises by minimizing points of contact when transferring fruits from conventional packaging to retail displays.

12. Vegetables are too loosely packed leading to abrasions

**Recommendations:** Packaging materials (such as trays, cups, wraps, liners, and pads) may be used to help immobilize the produce; in rural areas cloths, old papers, straw and other plant material can be used as buffers.

13. There are high losses in post-harvest vegetables mainly due to poor packaging.

**Recommendations:** Consider the use of returnable plastic crate system (RPCs) to significantly reduce the losses in vegetable post-harvest systems. The use of RPCs has been highlighted in a white paper drafted by the Postharvest Education Foundation<sup>51</sup>. RPCs required 39% less total energy, created 95% less solid waste, and generated 29% less total greenhouse gas emissions than display-ready containers.

An important factor to consider when making an investment in RPCs is the many shapes and sizes of plastic crates – must matching these characteristics properly to the intended use.

Recent examples of RPC use include 1) a USAID project in Afghanistan where RPCs were provided by a development project to tomato farmers for use during transport to market; 2) the Government of India's subsidy program for post-harvest investments, where 50% subsidies are provided for the purchase of RPCs; 3) Sri Lankan governmental efforts to promote the use of RPCs for fresh produce marketing; and 4) USAID Hort CRSP sponsored demonstrations of the use of RPCs for cold storage in Tanzania. Furthermore, FAO regional offices are currently introducing and promoting RPCs in Greater Mekong Sub-region countries for selected vegetables and fruits.

14. Management of crate system is difficult for the different stakeholders.

**Recommendations:** Different systems of management of RPCs exist, e.g. logistics of transport, cleaning and repairs, and getting empties back to growers.

1) *Grower/shipper owned*

This model works best when the buyer uses the crates for operations within the control of the RPC owner, such as for harvest, pre-cooling, or temporary storage.

2) *Plastic crate manufacturer owned/rented or leased to users*

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<sup>51</sup> Kitinoja, L. (2013) Returnable Plastic Crate (RPC) systems can reduce postharvest losses and improve earnings for fresh produce operations. PEF White Paper No. 13-01. The Postharvest Education Foundation: La Pine, Oregon, USA. 30 pp [http://www.fao.org/fsnforum/cfs-hlpe/sites/cfs-hlpe/files/files/Food\\_losses\\_waste/PEF%20RPCs%202013%20White%20paper%20pdf%20final.pdf](http://www.fao.org/fsnforum/cfs-hlpe/sites/cfs-hlpe/files/files/Food_losses_waste/PEF%20RPCs%202013%20White%20paper%20pdf%20final.pdf)

Most small farmers will need plastic crates only during the harvesting period. During other periods of the year, storing crates can become difficult, due to lack of storage space in their homes. Being able to rent or lease RPCs during the harvest period is therefore a practical approach.

### 3) *Deposit system*

In this system, the user pays the owner of the RPCs a deposit for every container s/he uses. The deposit equals, at minimum, the market value of the containers. The sender debits the recipient for this deposit, who does the same with the next recipient, and so on. The moment the RPCs reach their final destination in the marketing chain, they are collected by the owner. At this point, the owner refunds the deposit to the party from which the containers were collected. The deposits finance any losses and theft of the containers, so a tracking and tracing system to control the flow of containers is unnecessary. Finally, the high deposit cost also stimulates the quick return of the containers, so the rate of circulation of the RPCs is expected to be high.

### 4) *Produce buyer owned/managed/provided to users*

The RPCs are packed at the growers' locations, transported to the retailer's distribution center, and sent out to the retail stores where they go directly into displays. Empty containers are collected and shipped to a retailer-controlled site where they are washed and redistributed to growers for the next use. In most cases, a third party logistics provider controls the container returns.

In India, produce traders and modern retailers are using three approaches. In the first approach, they maintain extra crates in their inventories. The retailers maintain anywhere from two to five times the typical inventory of RPCs. They transport produce from destination A to B in these crates and when a sufficient volume of empty crates accumulates at destination B (a full truck load), they send them back to destination A in one backload.

The second approach being used is to sell the crates along with the produce. In every major produce market, crates are available and a few traders have a separate business involving the purchase/re-sale of used (second-hand) crates. In the case of tomatoes, for example, the supplier adds the cost of crates to the produce price. The buyer can then resell the used crates to state Agricultural Produce Marketing Committee (APMC) registered traders, and suppliers can purchase the used crates from dealers of the APMC markets.

The final approach is used by traders involved in reverse trade, for example, when two different types of produce from different production areas can be transported via the same set of RPCs. Tomatoes might be transported from destination A to B and then carrots transported from destination B to A using the same set of crates owned by the buyer or trader.

## ***Transporting:***

15. Poor infrastructure (roads, bridges) and lack of appropriate transport systems, including a lack of refrigerated transport.

**Recommendations:** Encourage investment from private sector and development projects, and policy support from government. Conduct cost-benefit studies on efficient and appropriate horticultural transport systems, including refrigerated transport, to evaluate the efficiency of the systems.

16. Existing transport methods lead to high losses and spoilage.

**Recommendations:** No overloading, avoid piling goods on top of each other, use trucks with shelves and divisions to reduce weight of upper goods on lower goods, protect the produce from direct sunlight and shade the loaded baskets, and unload goods properly/carefully. Need for improved containers and carrying strategies for individuals or bicycles, and strategies for keeping produce cool with shade and proper ventilation during transport. Develop a training course for transport system professionals to inform them about 'good transport management' practices and the benefits.

***Storage at collection centers, wholesale markets, retailers:***

17. Most products are not sorted prior to storage leading to degradation of products in storage.

**Recommendations:** If produce is to be stored, it is important to begin with a high-quality product. The produce must not contain damaged or diseased units, and containers must be well ventilated and strong enough to withstand stacking. In general, proper storage practices include temperature control, relative humidity control, air circulation, maintenance of space between containers for adequate ventilation, and avoiding incompatible product mixes.

18. Wholesalers and retailers have no knowledge about which crops can be stored together and which should not be stored together.

**Recommendations:** Commodities stored together should be capable of tolerating the same temperature, relative humidity, and level of ethylene in the storage environment. High ethylene producers (such as ripe bananas, apples, and cantaloupe) can stimulate physiological changes in ethylene sensitive commodities (such as lettuce, cucumbers, carrots, potatoes, and sweet potatoes) often leading to undesirable color, flavor, and texture changes. Wholesalers and retailers should be trained on these issues.

19. Placing products on the floor leads to rapid product deterioration.

**Recommendations:** Placing materials on the floor under sacks or cartons prevents dampness from reaching produce. Examples of such materials are:

- a. Waterproof sheets;
- b. Tarps;
- c. Poles; and
- d. Waterproof pallets.

20. In Nepal, there is little infrastructure for cooling of vegetables.

**Recommendations:** Several simple practices are useful for cooling and enhancing storage system efficiency, especially in developing countries where energy availability may be limited. Shade should be provided over harvested produce and packing areas. Buildings used for cooling and storage and vehicles used for transporting produce should have adequate cooling systems and ventilation.

For fresh market produce, any method of increasing the relative humidity of the storage environment (or decreasing the vapor pressure deficit between the commodity and its environment) will slow the rate of water loss. The best method of increasing relative humidity is to reduce temperature. Another method is to add moisture to the air around the commodity with mists, sprays, or, as a last resort, by wetting the store room floor.

21. There are several non-mechanical and mechanical cooling technologies (see Table XVI) that exist. Their cost-benefit ratio given the environmental and logistic conditions in Nepal should be evaluated.

**Recommendations:** Cooling provides the following benefits for perishable horticultural foods:

- Reduces respiration: lessens perishability;
- Reduces transpiration: lessens water loss, less shriveling;
- Reduces ethylene production: slows ripening;
- Increases resistance to ethylene action;
- Decreases activity of micro-organisms;
- Reduces browning and loss of texture, flavor, and nutrients; and
- Delays ripening and natural senescence.

**Table XVI: Examples of Non-mechanical technologies available for cooling**

Cold chain step	Small scale	Large scale
Pre-cooling systems	Portable evaporative forced air cooling systems	Slurry ice
Cold Storage	Zero energy cool chambers (ZECC) Evaporatively cooled cool rooms (charcoal coolers) Underground storage (root cellars) Night air ventilation High altitude storage Radiant cooling Solar chillers	Evaporatively cooled warehouses Underground storage (caves) High altitude storage Radiant cooling
Processing- chilling and freezing	None available	None available
Refrigerated transport	Evaporatively cooled insulated	Passive cooling (insulated

**Table XVI: Examples of Non-mechanical technologies available for cooling**

Cold chain step	Small scale	Large scale
	transport boxes or trailers	pallet covers)

*Note: Further information can be found in the Postharvest Education Foundation white paper on Use of cold chains for reducing food losses in developing countries.<sup>52</sup>*

**Table XVII: Examples of mechanical technologies available for cold storage**

Cold chain step	Small scale	Large scale
<b>Pre-cooling systems</b>	Portable forced air cooling systems	Vacuum cooling Forced air cooling Hydro-cooling
<b>Cold Storage</b>	Walk-in cold rooms CoolBot™ equipped cold room	Refrigerated warehouses
<b>Processing-chilling or freezing</b>	“Direct expansion” chilling of bulk milk “Instant” chilling of milk	Blast freezing IQF Vacuum cooling of packaged meats
<b>Refrigerated transport</b>	USDA Porta-cooler	Reefer vans Refrigerated marine containers Refrigerated intermodal containers (for road, rail and sea shipping)

*Note: Further information can be found in the Postharvest Education Foundation white paper on Use of cold chains for reducing food losses in developing countries.<sup>53</sup>*

### **Post-harvest processing:**

22. There is very little processing of harvested vegetables, simplest technology that is used in Nepal is solar drying, but the technology should be more promoted.

**Recommendations:** There is potential to use solar dryers to process chili, tomato, okra, onions, and other vegetables. Drying vegetables makes them less perishable products that can be marketed in more remunerative markets. There are many dryer models that exist<sup>54</sup>. There are several NGOs working on drying of products.

<sup>52</sup> <http://postharvest.org/Use%20of%20cold%20chains%20PEF%20white%20paper%202013-03%20final.pdf>

<sup>53</sup> <http://postharvest.org/Use%20of%20cold%20chains%20PEF%20white%20paper%202013-03%20final.pdf>

<sup>54</sup> <http://ucce.ucdavis.edu/files/datastore/234-1450.pdf> Chapter 10: Processing of horticultural crops

## REFERENCES & WEBLINKS

### I. TRAINING MATERIALS

Rice: [http://agmarknet.nic.in/rice-paddy-profile\\_copy.pdf](http://agmarknet.nic.in/rice-paddy-profile_copy.pdf)

Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition) Lisa Kitinoja and Adel A. Kader University of California, Davis. Postharvest technology  
<http://ucce.ucdavis.edu/files/datastore/234-1450.pdf>

### 2. USEFUL INTERNET SITES

[http://postharvest.ucdavis.edu/Most\\_Useful\\_Postharvest\\_Websites/](http://postharvest.ucdavis.edu/Most_Useful_Postharvest_Websites/) - overview of relevant websites for postharvest information compiled by the University of California, Davis

<http://www.fao.org/inpho/en/> - older information on post-harvest systems out of FAO, CIRAD & GTZ effort

<http://postharvestinstitute.illinois.edu/>

[http://postharvest.ucdavis.edu/Resources/most\\_useful\\_sites\\_06-10.pdf](http://postharvest.ucdavis.edu/Resources/most_useful_sites_06-10.pdf) - Most Useful internet sites for postharvest information

<http://alic.arid.arizona.edu/afghanistan/training/post%20harvest%20managementreduc.pdf> - Post harvest management of fruits and vegetables

[http://nesfp.nutrition.tufts.edu/downloads/guides/PL\\_HarvestGuide.pdf](http://nesfp.nutrition.tufts.edu/downloads/guides/PL_HarvestGuide.pdf) - Plain Language Guide to Harvesting Crops

[http://agritech.tnau.ac.in/postharvest/pht\\_faq.html](http://agritech.tnau.ac.in/postharvest/pht_faq.html) - Post harvest technology frequently asked questions

[http://www.ikisan.com/links/ap\\_harvest.shtml](http://www.ikisan.com/links/ap_harvest.shtml) - Post harvest operations, infra structure, storage, transporting and marketing

<http://www.extension.org/article/18354> - Respiration and ethylene and their relationship to postharvest handling

[http://books.google.com/books?id=Y4N54Wn6I8YC&pg=PA709&lpg=PA709&dq=green+beans+post+harvest&source=bl&ots=utOvwq76tO&sig=kpMDP6DeGalKIdPI2\\_nQlu-mr2o&hl=en&ei=HQpFTL-COs3\\_OciLsaIN&sa=X&oi=book\\_result&ct=result&resnum=1&ved=0CBEQ6AEwADhG#v=onepage&q&f=false](http://books.google.com/books?id=Y4N54Wn6I8YC&pg=PA709&lpg=PA709&dq=green+beans+post+harvest&source=bl&ots=utOvwq76tO&sig=kpMDP6DeGalKIdPI2_nQlu-mr2o&hl=en&ei=HQpFTL-COs3_OciLsaIN&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBEQ6AEwADhG#v=onepage&q&f=false) - Handbook of postharvest technology: cereals, fruits, vegetables, tea and spices

<http://www.okfarmtoschool.com/pdf/postharvest.pdf> - Postharvest handling of fruits and vegetables

### 3. VEGETABLE

<http://postharvest.tumblr.com/page/2> Postharvest education blog - lots of materials

<http://www.linkedin.com/groups/Postharvest-Training-3770124> Linkedin page for interaction on horticultural post-harvest issues with informal question & answer service

Prevention of Post-harvest Food Losses: Fruits, Vegetables, and Root Crops : a Training Manual

<http://www.fao.org/docrep/t0073e/t0073e00.HTM>

Postharvest Management of Fruit and Vegetables in the Asia-Pacific Region [http://www.apo-tokyo.org/00e-books/AG-18\\_PostHarvest/AG-18\\_PostHarvest.pdf](http://www.apo-tokyo.org/00e-books/AG-18_PostHarvest/AG-18_PostHarvest.pdf)

Small-Scale Postharvest Handling Practices: A Manual for Horticultural Crops (4th Edition). Lisa Kitinoja and Adel A. Kader University of California, Davis Postharvest Technology Research and Information Center <http://ucce.ucdavis.edu/files/datastore/234-1450.pdf>

Improving the Safety and Quality of Fresh Fruits and Vegetables: A Training Manual for Trainers (GAPS Manual) [http://jifsan.umd.edu/docs/gaps/en/GAPs\\_Manual\\_\(Compiled\).pdf](http://jifsan.umd.edu/docs/gaps/en/GAPs_Manual_(Compiled).pdf)

### 4. POST-HARVEST TRAINING PROGRAM – ONLINE

Applications are now being accepted for the 2014 Global Small-scale Postharvest E-Learning Program. The program takes place over a period of 14 months during 2014-2015 and provides training opportunities for 50 young horticultural professionals currently working in developing countries. The deadline for applications is December 31, 2013.

Training activities will include a wide assortment of reading, e-learning and fieldwork assignments to be undertaken by each trainee in their home country. Participants can choose the crops they are most interested in, and focus on the technologies most suitable for their region.

#### Fees and Materials

A registration fee of \$600 will be charged for the 2014 training program, with a 50% discount available for those located in less developed countries. PEF will supply all the required training materials and provide participants with weekly online interactive sessions, feedback and mentoring.

Priority will be given to those trainees who have the approval or permission of their supervisor, and it should be understood prior to applying that no financial compensation will be provided for the trainee's time away from work.

#### Program Completion

Those trainees who successfully complete all ten e-learning assignments and submit four written reports will receive a Postharvest Training of Trainers Certificate of Completion and a Postharvest Tool Kit valued at over US\$400. Successful trainees will be invited to travel at their own expense to work with

the PEF team during January or February 2015 for a week-long workshop on implementing training programs for small-scale horticultural farmers at one of many new Postharvest Training and Services Centers.

The top three participants in this year's program (as evaluated and selected by the training team and PEF board of directors) will be awarded a PEF travel grant valued at up to \$1,500 to cover their travel expenses.

<http://www.gcca.org/coldcon/2013/12/10/postharvest-education-foundation-accepting-applications-e-learning-program/>